

SCHEDULE OF RECOVERY TYPE 100% FRESH AIR UNITS(DOAS)

CODE	TYPE	QTY.	SUPPLY FAN DATA		MAX. OA (L/S)	RETURN AIR (RA) (L/S)	RETURN AIR FAN DATA		ENERGY RECOVERY WHEEL DATA				DISCH ARR.	REMARKS
			SUP AIR (L/S)	EXT SP (PASCAL)			RETURN AIR FAN DATA		EXHAUST AIR		FRESH AIR			
							RETURN AIR (L/S)	ESP (PASCAL)	AIR (L/S)	TEMP. (C)	AIR (L/S)	TEMP. (C) (DB/WB)		
ENERGY RECOVERY BASED AIR HANDLING UNITS														
TFAU-1	FLOOR MOUNTED HORIZONTAL DRAW THRU CENTRIFUGAL TYPE DOUBLE SKIN WITH RETURN FAN, RECOVERY WHEEL AND CHILLED WATER COIL	1	400	448	400	350	350	448	350	24	400	34 / 18	TD	SEE NOTES BELOW
TFAU-2		1	550	448	550	500	500	448	500	24	550	34 / 18	TD	
TFAU-3		1	2200	448	2200	2000	2000	448	2000	24	2200	34 / 18	TD	

NOTES:

- 1- FOR COIL DATA SEE SCHEDULE OF CHILLED/HOT WATER COILS.
- 2- THE TFU SHALL HAVE FOLLOWING MINIMUM SECTIONS
 - i) SUPPLY & RETURN AIR FAN SECTIONS
 - ii) COIL SECTION INCLUDING CHILLED/HOT WATER COIL
 - iii) FILTERS SECTION INCLUDING FOLLOWING FILTER MEDIA INSTALLED UP-STREAM OF THE FAN SECTION
 - a) 50MM THICK WASHABLE FILTER OF CLASS G4
 - b) THERMO WELDED SYNTHETIC FIBREGLASS BAG FILTERS (CLASS F7) OF MEDIUM LENGTH
- 4- THE PRESSURE DROP ACROSS THE ENERGY WHEEL SHALL NOT EXCEED TO 187 PASCAL.
- 5- TFAUs SHALL HAVE 50MM THICKNESS OF TFAU WALLS CONSTRUCTED WITH INJECTED POLYURETHANE
- 6- TFAUs SHALL BE SELECTED FOR ALTITUDE 2,230 METER ABOVE MEAN SEA LEVEL.
- 7- OFFERED EQUIPMENT SHALL BE AHRI OR EUROVENT CERTIFIED.
- 8- ENERGY RECOVERY WHEEL SHALL BE AHRI CERTIFIED SEPARATELY.

SCHEDULE OF WATER COILS FOR AIR HANDLING UNITS

SR. NO.	CODE	INSTALLED IN AHU NO.	QTY.	AIR THRU COIL L/S	MAX. COIL FV M/SEC	COOLING COIL (AIR SIDE)						COOLING COIL (WATER SIDE)				COIL HEATING DATA				FRESH AIR L/S
						TC (kW)	SHC (kW)	EDB deg C	EWB deg C	LDB deg C	LWB deg C	EWT deg C	LWT deg C	MAX.FLOW RATE Liter/Min	MAX. PD K.Pa	TH (kW)	EWT deg C	MAX.FLOW RATE Liter/Min	MAX. PD K.Pa	
18	CCHC-1	TFAU-1	1	400	2.8	12	9.5	25.5	16.2	11.2	10.3	6	12	MFR	60	20	60	MFR	60	400
19	CCHC-2	TFAU-2	1	550	2.8	15	12.7	30.6	24.6	23.1	22.5	6	12	MFR	60	25	60	MFR	60	550
20	CCHC-3	TFAU-3	1	2200	2.8	55	46.7	30.6	24.6	23.1	22.5	6	12	MFR	60	80	60	MFR	60	2200

ABBREVIATIONS:

CCHC:	COMBINATION COOLING HEATING COIL	EWB:	ENTERING AIR WET BULB TEMPERATURE
AHU:	AIR HANDLING UNIT	LDB:	LEAVING AIR DRY BULB TEMPERATURE
TC:	TOTAL COOLING CAPACITY	LWB:	LEAVING AIR WET BULB TEMPERATURE
SHC:	SENSIBLE COOLING CAPACITY	EWT:	ENTERING WATER TEMPERATURE
EDB:	ENTERING AIR DRY BULB TEMPERATURE	LWT:	LEAVING WATER TEMPERATURE

SCHEDULE OF FAN COIL UNITS

CODE	TYPE	SUPPLY FAN		ACCESSORIES	REMARKS
		AIR FLOW (L/S)	EXT SP (Pa)		
FCU-AA	HORIZONTAL CONCEALED CEILING SUSPENDED DUCT CONNECTED LOW STATIC TYPE WITH FILTER	190	57	SEE NOTES BELOW	FOR COIL DATA SEE SCHEDULE OF WATERCOILS FOR FAN COIL UNITS
FCU-A	-----DO-----	283	57	-----DO-----	-----DO-----
FCU-B	-----DO-----	377	57	-----DO-----	-----DO-----
FCU-C	-----DO-----	566	150	-----DO-----	-----DO-----
FCU-D	-----DO-----	755	50	-----DO-----	-----DO-----

NOTE

- 1- All FCUs shall be selected at medium speed.
- 2- FCUs motor shall be single phase, three speed type. Anti -corrosive body and drain pan
- 3- The FCUs noise level (DB) shall not be exceed to 60 DB.
- 4- ALL FCUs SHALL BE SUPPLIED WITH MATCHING TWO WAY MODULATION VALVE AND BACNET COMPATIBLE-THERMOSTAT

SCHEDULE OF WATER COIL FOR FAN COIL UNITS

SR. NO.	CODE	INSTALLED IN FCU NO.	AIR THRU COIL L/S	MAX. COIL FV M/S EC	COOLING (AIR SIDE)						COOLING (WATER SIDE)				COIL HEATING DATA			
					TC (kW)	SHC (kW)	EDB deg C	EWB deg C	LDB deg C	LWB deg C	EWT deg C	LWT deg C	MAX.FLOW RATE Liter/Min	MAX. PD K.Pa	TH (kW)	EWT deg C	MAX.FLOW RATE Liter/Min	MAX. PD K.Pa
1	CCHC-1	FCU-AA	190	2.8	4	3.4	25.9	16.3	12.5	11.8	6	12	17.1	45	7	60	17.1	45
2	CCHC-2	FCU-A	283	2.8	5.7	4.8	24.6	16.5	12.5	11.7	6	12	14.7	45	9.5	60	14.7	45
3	CCHC-3	FCU-B	377	2.8	7	5.9	24.7	17.0	13.0	12.3	6	12	9.0	45	12	60	9.0	45
4	CCHC-4	FCU-C	567	2.8	10.5	8.8	24.7	17.0	13.0	12.3	6	12	9.0	45	15	60	9.0	45
5	CCHC-5	FCU-D	755	2.8	14.5	12.3	25.9	17.2	12.8	12.0	6	12	12.1	45	18	60	12.1	45

CCHC: COMBINE COOLING HEATING COIL

FCU : FAN COIL UNIT

TC : TOTAL COOLING CAPACITY

SHC : SENSIBLE COOLING CAPACITY

EWB : ENTERING WET BULB TEMPERATURE

EWT : ENTERING WATER TEMPERATURE

LWT : LEAVING WATER TEMPERATURE

TH : TOTAL HEATING CAPACITY

EAT : ENTERING AIR TEMPERATURE

LAT : LEAVING AIR TEMPERATURE

FV : COIL FACE VELOCITY

PD : PRESSURE DROP

NOTE

- 1- All coils shall be selected at 0.45 mm thickness of copper tube.
- 2- FCUs motor shall be single phase, three speed type.
- 3- FCU-A (to be installed in ATC cabin and ARFF cabin) shall have maximum noise level of not exceeding 45dBA measured at 1.5 meters distance.
- 4- The FCUs noise level (DB) shall not be exceed to 50 DB for all other types

AIR INLETS / OUTLETS – EQUIPMENT SCHEDULE

1	Type	Equipment Schedule	Service	Material	Reference Make / Model	Finish	Colour	Accessories
A	Ceiling Supply Diffuser	Square, removeable cone type	Supply	Aluminium Extruded	Tuttle & Bailey, TROX, AirMate, Krueger, Nailor	Anodized	As required by Engineer	As specified
B	Ceiling Return Diffuser	Square, removeable cone type	Return	Aluminium Extruded		Anodized	As required by Engineer	As specified
C	Supply Air Register	Side Wall adjustable vertical & horizontal bars register	Supply	Aluminium Extruded		Anodized	As required by Engineer	As specified
D	Return Air Register	Side Wall adjustable vertical & horizontal bars register	Return	Aluminium Extruded		Anodized	As required by Engineer	As specified
E	Return Air Grille	Deflected fixed horizontal Bar Grille	Return	Aluminium Extruded		Anodized	As required by Engineer	As specified
F	Transfer Grille	Deflected fixed horizontal Bar Grille	Return	Aluminium Extruded		Anodized	As required by Engineer	As specified
G	OA Louver	Outdoor Air Intake Louvre	Intake	Aluminium Extruded		Anodized	As required by Engineer	Insect Screen & Filter
H	EA Louver	Exhaust Air Outlet Louvre	Exhaust	Aluminium Extruded		Anodized	As required by Engineer	Relief Damper
I	—	—	—	Aluminium Extruded		Anodized	As required by Engineer	As specified
J	Filter-Back Return Grille	FCU Return	Return	Aluminium Extruded		Anodized	As required by Engineer	—
K	Supply Air Grille	Adjustable vertical & horizontal bars grille	Supply	Aluminium Extruded		Anodized	As required by Engineer	—
L	Linear Return Grille	Continuous Linear Grille for Return Air	Return	Aluminium Extruded	T & B Imperialine 6000, slots as per Drg, TROX, AirMate, Krueger, Nailor	Anodized	As required by Engineer	—
M	Linear Supply Grille (drawing shows "LIEAR")	Continuous Linear Air Grille for Supply Air	Supply	Aluminium Extruded		Anodized	As required by Engineer	With Pattern Controller
N	Wire Mesh	Wire mesh at duct opening	Return / Exhaust	GI ½" × ½" wire mesh	—	—	—	—
Z	Supply Air	Eye Ball Jet Diffuser (Adjustable)	Supply	Aluminium Extruded	T & B, TROX, AirMate, Krueger, Nailor	Anodized	As required by Engineer	—

SECTION 0730 – SPECIAL PROVISIONS FOR MECHANICAL WORKS

PART 1 – GENERAL

1.1 SCOPE OF WORK

Design, preparation of installation/erection drawings, obtaining government/Employer approvals/certificates, fabrication, installation, testing, commissioning, maintenance for stipulated period, training of Employer's staff. All miscellaneous equipment/work to render equipment ready. All wiring and controls beyond power supply point. Inspection of already constructed civil works. Cutting, patching, repairing. Provide installation, operation, maintenance manuals, spares lists, drawings, diagrams, test certificates. Training. Maintenance during defects liability period (365 days after handing over).

1.2 CODES AND STANDARDS

ASME, BS/EN, AWS, NFPA, ASTM, NEMA, IEE, AISC, ICC, Building Code of Pakistan.

1.3 QUALITY STANDARD

If equipment not from recommended manufacturers, only manufacturers with proven record considered.

Manufacturer: Equipment of USA, Western Europe & Japan origin only (or license from same with guarantee). Min 30 years' experience. Name, part numbers, serial numbers on major components. At least 30 offered units successful operation in Pakistan for min 3 years. New, latest design.

Installer/Supplier: Authorized sole distributor/dealer/agency holder from manufacturer. PEC Registration in relevant category, NTN certificate. Successful experience of supply/installation of offered equipment: average min 20 units over last five years. Successful experience of maintenance: average min 15 units over last five years.

1.4 PRODUCT HANDLING AND STORAGE

Contractor entire responsibility.

1.5 INSPECTION AND CONTROL

Engineer may inspect at any time. **Pre-shipment Inspection** for Passenger Lifts, Escalators, Passenger boarding bridges, Baggage handling system, Hydrant Refueling System. One Employer rep + one Engineer rep. Contractor provides travel, visas, boarding, lodging, daily allowance. Submit test procedures/protocols for approval. 3 weeks notice. **Inspection at Site Works:** Engineer inspects after delivery. **Damages:** Contractor responsible for damage during transport, storage, installation.

1.6 DRAWINGS AND SUBMITTALS

Technical Data Sheets: Completed with technical literature. **Outline Drawings:** Arrangement of equipment and electrical installations. **Design Drawings/Shop Drawings:** Allow 3 weeks for review. Show final arrangement, max dynamic/static loads, dimensions/locations of services/embedded parts/electrical connections, wiring/control logic diagrams. **As Built / As-Installed Drawings:** Size A1 min. All items legible. **Installation, Operating and Maintenance Manuals:** Four sets. Contents: Index, general description, fault detection, emergency directions, safety control settings, equipment

list with manufacturer/agent/nameplate data, dismantling/installation/operating/maintenance instructions, list of spare parts, list of essential tools, as-installed drawings.

1.7 OPERATION AND MAINTENANCE

Maintenance During Defects Liability Period: Remedy/replace defective parts. Continuous weekly routine service, emergency service short notice. Skilled personnel. Includes inspection, lubrication, supply of consumables, oil/grease, cotton waste, running adjustments, cleaning. **Register of Service and Maintenance:** Record of all services, maintenance, repair work in duplicate.

1.8 SPARES AND TOOLS FOR SERVICING AND MAINTENANCE

Spare Parts: Consumables for 2 years operational duties. Normal spares recommended for 2 years after DL period. **Tools & Instruments:** Complete set in tool boxes not used by Contractor during installation/testing/commissioning/DLP. List includes flat/ring spanner sets, screw driver set, allen key set, T socket spanner set, tester, nose plier, plier, cutter plier, hammer (2 lb), adjustable wrench, Fluke digital multimeter, hacksaw frame with blade, 5m measuring tape, head held LED torch, insulation tape set (red,yellow,blue,green), grease gun, oiling can, toolbox. Quantity 4 each.

1.9 PAINTING & FINISHES

Thoroughly cleaned, freed from oil/grease. Approved primer, undercoats, finishing coats. Stainless steel finish No.4 unless specified.

1.10 TESTING AND COMMISSIONING

Contractor gives 7 days notice. If fails, Engineer may call upon Contractor under 7 days notice; if still fails, tests by other agency at Contractor's expense. Contractor supplies utilities, labour, apparatus, instruments. Each section to operate within specified limits for 1 year after Testing and Commissioning (under Contractor's charge).

1.11 TEST CERTIFICATES AND REPORTS

Copies of test certificates/reports: critical materials, factory tests, pre-shipment test report, testing & commissioning report.

1.12 TRAINING

Free training and instruction for Employer's maintenance staff. Instructor competent and experienced. Syllabus details, hours, field instruction, number of Employer's personnel included with Bid.

1.13 FITNESS CERTIFICATE

Written guarantee endorsed in Employer's name that material and workmanship conform to international standards. During last month of Defect Liability Period, demonstrate all equipment operating as per specifications. If equipment out of order >10 days (or as per Conditions of Contract), DLP extended.

1.14 WARRANTY

Per respective sections, from TOC, endorsed in Employer's name.

PART 2 - MEASUREMENT AND PAYMENT

No payment shall be made for the works involved within the scope of this section of specifications unless otherwise specifically stated in the Bill of Quantities or herein. The cost thereof shall be deemed to have been included in the quoted unit rate of other items of the Bill of Quantities.

SECTION 0740 - CNS EQUIPMENT
DIVISION 01 – GENERAL REQUIREMENTS

PART 1 – GENERAL

1.1 SCOPE OF WORK

The Contractor shall undertake the complete planning, design, engineering, manufacturing, supply, installation, integration, testing, commissioning, and handover of all Communication, Navigation, and Surveillance (CNS) equipment required for the Air Traffic Control (ATC) Tower and Fire Station at Skardu Airport. The work shall be executed on a turn-key basis and shall ensure full compliance with the technical specifications, drawings, applicable international standards, and the Bill of Quantities (BOQ).

The scope includes, but is not limited to:

- **VHF (AM) Air Band Communication System** – transceivers configured in main/standby pairs with dual-cavity combiners and omnidirectional antennas.
- **UHF (AM) Air Band Communication System** – transceivers configured in main/standby pairs with associated filters and antennas.
- **HF Communication System** – transceivers (1 kW) and transceiver 125 watts with broadband antennas.
- **Radio Remote Controllers** – with touch-screen, headset, foot pedal, and UPS backup.
- **Remote Control and Monitoring System (RCMS)** – software suite with workstation and laptop, quantity 4 user and 50 device licenses.
- **Digital Voice Logging System (DVLS)** – dual redundant 48-channel recorder with synchronized replay, 31-day online storage.
- **Antenna Systems, Combiners, Filters, and RF Distribution** – including VHF dual-cavity combiners, UHF dual filters, VHF/UHF antennas, low-loss coaxial cable, etc.
- **Power Supply Systems** – 13.4 to 48 VDC (adjustable) power system with lithium battery bank (≥2 hours backup), double conversion online UPS, and low power control AVR/UPS.
- **Network Infrastructure** – managed Layer 2/3 Ethernet switches with dual LAN redundancy capability.
- **Automated Weather Observing System (AWOS)** – single-runway ICAO CAT I system including sensors, central data unit, and integration.
- **ATC Console Furniture** – ergonomic working positions with integrated monitor mounts and cable management.
- **AMHS Terminal** – all-in-one desktop computer and dot-matrix printer with redundant lines through PTCL Fiber and Satellite.
- OCC room with all required equipment.
- Separate earth pit for CNS equipment and building with lightning arrester.

- Any other system required for complete functioning of ATC equipment installed.
- Factory Acceptance Tests (FAT), Site Acceptance Tests (SAT), and training – as detailed in the BOQ.

All equipment and materials shall be new, of proven technology, and shall have been successfully deployed in civil aviation environments with similar operational and climatic conditions.

1.2 CONTRACTOR'S RESPONSIBILITY AND INTEGRATION

The Contractor shall act as the **General Integrator** for all subsystems within this scope and shall bear full system-wide responsibility for the design, selection, supply, installation, and integration of all components. The Contractor shall ensure that all subsystems (VHF, UHF, HF, recording, remote control, monitoring, weather, power, etc.) work together as a single, fully functional, and interoperable system.

The Contractor shall coordinate with other contractors (e.g., for civil works, fire telephone system, master clock system) and shall provide all necessary interface control documents (ICDs) to ensure seamless integration.

1.3 AMBIENT CONDITIONS

All equipment shall be designed and tested to operate without derating under the following ambient conditions at Skardu Airport:

Parameter	Value
Maximum outdoor temperature	50°C
Minimum outdoor temperature	-25°C
Maximum indoor (non-AC) temperature	40°C
Maximum indoor (air-conditioned) temperature	30°C
Maximum relative humidity	100% (at 43°C)
Altitude	2230 m above mean sea level
Wind velocity	180 km/h
Seasonal snow	Up to 6 inches

1.4 POWER SUPPLY CONDITIONS

Equipment shall operate satisfactorily with the following power supply variations without any derating:

- **AC Supply:** 100-260 V $\pm 10\%$, single phase; 400 V $\pm 10\%$, three phase; frequency 50 Hz ± 2 Hz.
- **DC Supply:** 13.4 to 48 V DC adjustable $\pm 20\%$ (or as required by equipment).

1.5 QUALITY ASSURANCE

The Contractor's quality management system shall be ISO 9001 certified. All equipment shall be manufactured under a certified quality assurance program. Certificates of conformity shall be provided.

1.6 EQUIVALENT PRODUCTS AND MINIMUM OEM QUALIFICATION CRITERIA

1.6.1 General Requirement

Equivalent products shall be considered only where they demonstrably meet or exceed all specified technical requirements, performance parameters, environmental conditions, applicable international standards, and interoperability requirements defined in these Specifications. Compliance shall be established through complete and verifiable technical documentation submitted with the bid.

1.6.2 Proven Technology and Application

The offered product shall be of proven design and mature technology, and shall have been in successful operational service in civil aviation environments (preferably CNS/ATC applications) under similar environmental and operational conditions.

1.6.3 Original Equipment Manufacturer (OEM) Experience

The manufacturer (OEM) of the offered product shall have a minimum of ten (10) years' continuous experience in the design, engineering, and production of same equipment.

1.6.4 Supply and Operational Track Record

The OEM shall have supplied, installed, and commissioned not less than five hundred (500) units of the same or substantially similar product worldwide during the last five (5) years. Out of these, a minimum of fifty (50) installations shall be in active and satisfactory operational service.

1.6.5 Documentation and Evidence

The bidder shall submit comprehensive documentary evidence in support of compliance, including but not limited to:

- (a) Type test reports and certificates of compliance with applicable international standards (e.g., IEC, ICAO, EUROCAE, IEEE, ETSI, or equivalent);
- (b) Detailed technical datasheets and performance specifications;
- (c) Client references with contact details and evidence of satisfactory operation;
- (d) Supply, installation, and commissioning records; and
- (e) Factory Acceptance Test (FAT) and Site Acceptance Test (SAT) procedures and reports, where applicable.

1.6.6 Product Lifecycle and Support

The offered product shall be in current production and shall not be based on prototype, developmental, obsolete, or end-of-life technology. The OEM shall guarantee availability of spare parts, technical support, and software/firmware updates for a minimum period of ten (10) years from the date of Final Acceptance.

1.6.7 Right of Verification and Rejection

The Employer/Engineer reserves the right to verify all submitted information and supporting documents. Any product for which the information is found to be incomplete, inconsistent, misleading, or unverifiable shall be rejected. Failure to comply with any requirement of this Clause shall render the bid non-responsive and liable to rejection without further evaluation.

DIVISION 02 – ELECTRICAL

PART 1 – GENERAL

1.1 SCOPE

This section specifies general electrical requirements common to all electrical work within the CNS equipment installation at Skardu Airport. This includes power distribution, wiring methods, circuit protection, identification, and associated accessories necessary for a complete and fully functional electrical infrastructure supporting all communication, navigation, surveillance, and weather systems.

The Contractor shall provide all labor, materials, equipment, and services required for the complete electrical installation in accordance with the contract documents, applicable codes, and industry best practices. All work shall be performed in a professional manner to ensure reliability, safety, and maintainability consistent with critical air traffic control applications.

1.2 REFERENCES

The electrical installation shall comply with the latest editions of the following standards, codes, and regulations. Where conflicts exist, the more stringent requirement shall apply.

Standard/Code	Title	Application
International		
IEC 60364	Electrical Installations of Buildings	Overall electrical installation
IEC 60446/60445	Basic and Safety Principles for Man-Machine Interface, Marking and Identification	Conductor identification
IEC 60529	Degrees of Protection Provided by Enclosures (IP Code)	Enclosure ratings
IEC 61000 Series	Electromagnetic Compatibility (EMC)	Immunity and emissions
IEC 62305	Protection Against Lightning	Lightning protection
IEC 60950 / 62368-1	Safety of Information Technology Equipment	Equipment safety
IEEE 1100	Recommended Practice for Powering and Grounding Electronic Equipment	Power quality and grounding
IEEE C62.41	Surge Voltages in Low-Voltage AC Power Circuits	Surge protection
National / Local		

Standard/Code	Title	Application
Pakistan Electric Power Code (PEPC)	As adopted by NEPRA	Local regulatory compliance
Pakistan Engineering Council (PEC)	Building and Electrical Codes	Local engineering practice
Water and Power Department, Government of Gilgit-Baltistan (GB Power)	Distribution Standards	Utility interface requirements
Industry Best Practices		
Schneider Electric	Cahier Technique	Power distribution design
Eaton	Bussmann Series SPD Handbook	Surge protection coordination
Siemens	Low-Voltage Switchgear and Distribution	Panel design standards
Rittal	Enclosure and Climate Control Guidelines	Cabinet ventilation and protection

The Contractor shall also comply with any additional requirements specified by the equipment manufacturers regarding power quality, grounding, and environmental conditions.

1.3 SUBMITTALS

The Contractor shall submit the following documents for review and approval by the Engineer prior to commencement of any electrical work:

a) Shop Drawings:

- Single-line diagrams (SLD) showing all power distribution from utility entry to final equipment outlets.
- Riser diagrams indicating vertical distribution.
- Panel schedules detailing circuit numbers, loads, breaker sizes, and wire gauges.
- Conduit routing plans with raceway sizes and locations.
- Receptacle and equipment outlet layouts.
- Lighting layout (if applicable).
- Load calculations for all distribution panels, UPS, and DC systems.

b) Wiring and Connection Diagrams:

- Interconnection diagrams between panels, UPS, DC systems, and CNS equipment.
- Terminal strip layouts and wiring details.
- Control wiring schematics for remote monitoring and alarm interfaces.

c) Product Data:

- Manufacturer's catalogue cuts and technical data for all electrical components:
 - Distribution panels and circuit breakers
 - Conduit, fittings, and boxes
 - Wiring devices (receptacles, switches)
 - Surge protective devices (SPDs)
 - Cable tray systems
 - Labelling systems

d) Nameplate Schedules:

- Schedule of all electrical panels, cabinets, and major equipment with designated identification numbers.
- Nameplate content and format for all panels and devices.

e) Test and Commissioning Plans:

- Electrical testing procedures and acceptance criteria.
- Insulation resistance test records.
- Continuity and polarity test records.
- Ground resistance test reports.

f) As-Built Documentation:

- Final as-built drawings reflecting all field modifications.
- Updated single-line diagrams and panel schedules.
- Cable and conduit as-built routing.

PART 2 – PRODUCTS

2.1 WIRING AND CONDUCTORS

2.1.1 General Requirements

- All conductors shall be **copper**, stranded, with insulation rated for 600 V, 90°C minimum.
- Conductor sizes shall be based on the calculated load, voltage drop, and short-circuit rating, but in no case smaller than:
 - Lighting circuits: 2.5 mm²

- Power circuits (general): 4 mm²
- Feeder circuits: As calculated (minimum 6 mm²)
- Conductors shall be sized for a maximum voltage drop of 2% at the furthest outlet and 3% total from service entry.

2.1.2 Conductor Insulation Types

- **General purpose:** PVC insulated, 600 V, 90°C (e.g., IEC 60227 / BS 6004).
- **Fire-resistant circuits:** LSZH (Low Smoke Zero Halogen) or similar where required for safety circuits.
- **Flexible connections:** Multi-strand flexible cord with appropriate strain relief.

2.1.3 Cable Types

- **Single-core cables:** For panel wiring and conduit installations.
- **Multi-core cables:** For multi-circuit runs where grouped.
- **Armored cables:** For outdoor or exposed runs where mechanical protection is required (e.g., SWA).

2.1.4 Manufacturer Standards

Acceptable manufacturers include, but are not limited to: Prysmian, Nexans, LS Cable & System, General Cable, Pak Cables (subject to meeting all technical requirements), or equivalent meeting specification requirements as per Clause 1.6 of Division 01 General Requirements.

2.2 CONDUITS, RACEWAYS, AND FITTINGS

2.2.1 Conduit Types

Location	Conduit Type	Standard	Application
Exposed (equipment rooms)	Rigid Steel Conduit (RGS)	IEC 61386 / UL 6	Maximum mechanical protection
Concealed (walls, ceilings)	Electrical Metallic Tubing (EMT)	IEC 61386 / UL 797	Lightweight, protected locations
Underground (exterior)	Rigid PVC (Schedule 80)	IEC 61386 / UL 651	Corrosion resistant, direct burial
Flexible connections	Liquid-tight Flexible Metal Conduit (LFMC)	IEC 61386 / UL 360	Final connections to equipment
Cable tray	Perforated or solid bottom ladder tray	IEC 61537 / NEMA VE 1	Large cable runs

2.2.2 Conduit Sizing

- Conduits shall be sized per NEC/IEC requirements with a minimum fill of 40% for power conductors and 50% for control conductors.
- Minimum conduit size: 20 mm ($\frac{3}{4}$ ") for branch circuits.

2.2.3 Fittings and Accessories

- All fittings shall be of the same material as the conduit.
- Boxes shall be galvanized steel with appropriate knockouts.
- Pull boxes and junction boxes shall be sized for the number and size of conductors.

2.2.4 Manufacturer Standards

Acceptable manufacturers include Atkore (Allied, Calbrite), Legrand (Wiremold, Ortronics), Schneider Electric (Square D), Eaton (Crouse-Hinds), or equivalent meeting Clause 1.6.

2.3 DISTRIBUTION PANELS AND CIRCUIT BREAKERS

2.3.1 Panelboards

- **Type:** Dead-front, circuit breaker type, suitable for location (indoor/outdoor, NEMA 1 / IP31 or NEMA 12 / IP54 as required).
- **Construction:** Heavy-gauge steel, powder-coated finish.
- **Main breaker:** Molded case circuit breaker (MCCB) with adjustable trip settings.
- **Branch breakers:** Miniature circuit breakers (MCBs), thermal-magnetic, 10 kAIC minimum.
- **Busbars:** Copper, sized for the panel rating.
- **Neutral and ground bars:** Isolated neutral (floating) and separate equipment ground bars.

2.3.2 Circuit Breaker Characteristics

- **Voltage rating:** 230/400 V, 50 Hz.
- **Current rating:** As per load calculations.
- **Interrupting capacity:** Minimum 10 kA (higher where available fault current exceeds).
- **Tripping characteristics:** Type C for general circuits, Type D for motor loads.

2.3.3 Manufacturer Standards

Acceptable manufacturers include Schneider Electric (Square D, Merlin Gerin), Eaton (Cutler-Hammer), Siemens (Sentron), ABB (S series), or equivalent meeting Clause 1.6.

2.4 SURGE PROTECTIVE DEVICES (SPDs)

2.4.1 AC Power SPDs

- **Type 1 (10/350 μ s):** Installed at main distribution panel. Voltage protection level (U_p) $\leq$ 2.5 kV. Nominal discharge current (I_n) $\geq$ 20 kA per phase.
- **Type 2 (8/20 μ s):** Installed at sub-panels and UPS outputs. $U_p \leq$ 1.5 kV, $I_n \geq$ 20 kA per phase.

- **Type 3:** Installed at sensitive equipment outlets (as required).

2.4.2 Data and Signal SPDs

- **Ethernet:** CAT6/6a shielded, with gas discharge tube and clamping diodes.
- **RF Coaxial:** In-line, frequency-specific (118-137 MHz, 225-400 MHz, 2-30 MHz), with low insertion loss.
- **Control signals:** Multi-pair protectors for analog and digital lines.

2.4.3 Manufacturer Standards

Acceptable manufacturers include DEHN, Phoenix Contact, Citel, Raycap, Eaton Bussmann, or equivalent meeting Clause 1.6.

2.5 WIRING DEVICES

2.5.1 Receptacles

- **Type:** Industrial grade, 13 A, 230 V AC, switched.
- **Configuration:** UK-type (BS 1363) for general use; IEC 60309 (CEE 17) for high-current equipment.
- **Enclosure:** Flush or surface mount as required.

2.5.2 Switches

- **Type:** Industrial grade, 10 A, 230 V AC, single-pole or multi-way as required.
- **Configuration:** Toggle or rocker as per architectural finish.

2.5.3 Manufacturer Standards

MK Electric (Honeywell), Legrand, Schneider Electric (Lisse, Clipsal), Hager, or equivalent meeting Clause 1.6.

2.6 CABLE TRAY AND SUPPORTS

2.6.1 Cable Tray

- **Type:** Ladder tray, galvanized steel, with 4" side rails.
- **Finish:** Hot-dip galvanized or pre-galvanized.
- **Accessories:** Splices, drop-outs, covers where required.

2.6.2 Supports

- Unistrut or equivalent channel strut system for equipment mounting and cable support.
- Threaded rod and trapeze hangers for overhead runs.

2.6.3 Manufacturer Standards

Unistrut (Atkore), Eaton (B-Line), Thomas & Betts (ABB), or equivalent meeting Clause 1.6.

2.7 IDENTIFICATION AND LABELING

2.7.1 Labelling System

- **Panel labels:** Engraved laminated plastic, 2 mm thick, black lettering on white background.
- **Circuit labels:** Heat-shrink sleeve or self-laminating wrap-around type.
- **Cable labels:** Durable nylon or vinyl tags with heat-shrink tubing.

2.7.2 Label Content

- **Distribution panels:** "P-XXX" – main distribution, "PP-XXX" – sub-panel.
- **Circuits:** Panel designation, circuit number, load description (e.g., "P-01-C12 – VHF Cabinet 1").
- **Conductors:** Phase and neutral identification.

2.7.3 Manufacturer Standards

Brady (BMP series), Panduit, Dymo (Industrial), or equivalent meeting Clause 1.6.

PART 3 – EXECUTION

3.1 GENERAL INSTALLATION REQUIREMENTS

3.1.1 Coordination

- The Contractor shall coordinate electrical installation with other trades (civil, mechanical, data communications, etc.).
- Rough-in shall be completed prior to ceiling and wall finishes.
- All electrical work shall be scheduled to minimize disruption to airport operations.

3.1.2 Workmanship

- All work shall be performed by licensed electricians with demonstrated experience in industrial and airport environments.
- Installations shall be neat, symmetrical, and accessible for maintenance.
- Conduits shall be run parallel or perpendicular to building lines unless otherwise approved.

3.2 RACEWAY INSTALLATION

3.2.1 Conduit Installation

- Conduits shall be installed with proper supports at intervals not exceeding:
 - EMT: 3 m (10 ft)
 - RGS: 3.5 m (12 ft)
 - PVC: 1.5 m (5 ft)
- Bends shall be made with a conduit bender; no kinking or flattening.
- Conduit ends shall be reamed to remove burrs.
- Threaded connections shall be made with appropriate couplings and bonding jumpers.

3.2.2 Underground Conduits

- Trenches shall be excavated to depth of 600 mm minimum.
- PVC conduits shall be bedded in 100 mm of sand, covered with warning tape, and backfilled.
- Conduits shall be sealed at ends to prevent water ingress.

3.2.3 Cable Tray Installation

- Cable tray shall be installed on top roof of control tower to ECR for CNS installations.
- Cable trays shall be installed level and straight, supported at 1.5 m intervals.
- Trays shall be bonded to the grounding system at intervals not exceeding 15 m.
- Cables shall be neatly laid with appropriate separation between power and data.

3.3 CONDUCTOR INSTALLATION

3.3.1 Pulling

- Conductors shall be pulled using approved lubricants (for PVC, not for rubber).
- Pulling tensions shall not exceed manufacturer recommendations.
- Conductors shall not be pulled over sharp edges.

3.3.2 Terminations

- Conductors shall be terminated with compression lugs or screw terminals as appropriate.
- Torque values shall follow manufacturer specifications.
- No conductors shall be nicked or cut during stripping.

3.3.3 Spare Conductors

- Minimum 20% spare conductors shall be provided in each conduit (subject to fill calculations).
- Spare conductors shall be terminated and labelled.

3.4 PANELBOARD INSTALLATION

3.4.1 Mounting

- Panels shall be mounted plumb and level.
- Panels shall be installed with clear working space of 1 m in front.
- Panels shall be labelled with circuit directory.

3.4.2 Wiring

- Branch circuits shall be neatly arranged and bundled.
- Neutral and ground conductors shall be terminated on separate bars.
- All connections shall be torqued per manufacturer's requirements.

3.5 SURGE PROTECTIVE DEVICE INSTALLATION

3.5.1 AC SPDs

- Type 1 SPDs shall be installed at the main distribution panel with conductor length minimized (<0.5 m).
- Type 2 SPDs shall be installed at sub-panels and UPS outputs.
- All SPDs shall have indicator lights showing status.

3.5.2 Data and Signal SPDs

- Ethernet SPDs shall be installed at building entry and at equipment cabinets.
- Coaxial SPDs shall be installed at the point of entry for all antenna feeders.
- Grounding conductors for SPDs shall be as short and direct as possible.

3.6 LABELING

3.6.1 Panel Labels

- Each panel shall have a permanent nameplate with panel designation and voltage rating.
- Circuit directories shall be completed and inserted in clear plastic holders.

3.6.2 Conduit and Cable Labels

- Each conduit run shall be identified with a tag at both ends.
- Each cable shall be identified with heat-shrink labels at termination points.
- Labels shall be legible from a distance of 1 m.

3.7 ELECTRICAL TESTING

3.7.1 Pre-Energization Tests

- **Insulation resistance:** Test each circuit at 500 V DC; minimum 1 M Ω .
- **Continuity:** Verify all circuit conductors and grounding.
- **Polarity:** Verify correct phase and neutral connections.
- **Ground resistance:** Measure earth electrode system resistance; $\leq 1 \Omega$.

3.7.2 Post-Energization Tests

- **Voltage measurement:** Verify voltage levels at all outlets ($\pm 5\%$ of nominal).
- **Phase rotation:** Verify correct rotation for three-phase equipment.
- **SPD operation:** Verify status indicators.
- **Load testing:** Verify circuit breakers do not trip under normal load.

3.7.3 Test Equipment

- All test equipment shall be calibrated and traceable to national standards.
- Test results shall be documented and submitted to the Engineer.

3.8 FINAL ACCEPTANCE

3.8.1 Documentation

- Submit as-built drawings showing actual conduit routes, panel schedules, and cable terminations.
- Provide test reports for all circuits.

3.8.2 Inspection

- The Engineer shall inspect all electrical work prior to covering (rough-in) and after completion.
- Any deficiencies shall be corrected at no additional cost.

PART 4 – SPECIAL PROVISIONS FOR CNS EQUIPMENT

4.1 POWER QUALITY REQUIREMENTS

Given the sensitive nature of CNS equipment, the following additional requirements shall apply:

4.1.1 Voltage Regulation

- Power supplied to VHF/UHF radios, DVLS servers, RCMS workstations, and AWOS shall be within $\pm 5\%$ of nominal.
- UPS systems shall provide clean, conditioned power meeting IEC 62040-3 Class 1 (voltage and frequency independent).
- Low voltage control AVR 80 to 260 VAC necessary.

4.1.2 Harmonic Distortion

- Total Harmonic Distortion (THD) at the input to CNS equipment shall not exceed 5%.
- The Contractor shall verify compatibility between UPS output and equipment power supplies.

4.1.3 EMI/RFI Protection

- Power feeders to CNS equipment shall be separated from data and RF cables by a minimum of 300 mm.
- Where crossing is unavoidable, crossing shall be at 90° .
- All power circuits serving CNS equipment shall have surge protection as specified.

4.2 DEDICATED CIRCUITS

- Each radio transceiver, transmitter, receiver, and recorder server shall be served by a dedicated circuit breaker.
- Circuits shall be clearly labeled with the equipment designation.
- No other equipment shall be connected to these circuits.

4.3 DC POWER DISTRIBUTION

- DC power (48 V) from the rectifier system shall be distributed to radios via fused distribution panels.

- DC cabling shall be color-coded: red for positive (+), black for negative (-), green/yellow for ground.
- DC circuits shall be sized for a voltage drop $\leq 2\%$ from battery to load.

DIVISION 03 UNINTERRUPTIBLE POWER SUPPLIES (UPS)

PART 1 – GENERAL

1.1 SCOPE

This section specifies the requirements for double-conversion online uninterruptible power supply (UPS) systems that provide conditioned, continuous power to critical CNS equipment at Skardu Airport, including:

- ATC Tower (remote controllers, displays, communications equipment)
- Radio Equipment Room (VHF/UHF/HF radios, DVLS servers, RCMS, network switches)
- Fire Station (compact radio controllers, communications equipment)
- OCC room for emergency handling
- CNS technical workshop

The UPS systems shall protect against all nine power disturbances defined by IEEE 1159. The systems shall provide seamless transition between utility power, battery power, and bypass modes, ensuring zero transfer time for critical loads.

The Contractor shall be responsible for the complete engineering, supply, installation, testing, and commissioning of all UPS systems, including batteries, battery cabinets, input/output distribution, remote monitoring interfaces, and all necessary accessories.

1.2 REFERENCES

The UPS systems and associated components shall comply with the latest editions of the following standards.

Standard	Title	Application
IEC 62040-1	Uninterruptible Power Systems – General and Safety Requirements	Overall UPS safety
IEC 62040-2	Uninterruptible Power Systems – EMC Requirements	Electromagnetic compatibility
IEC 62040-3	Uninterruptible Power Systems – Performance and Test Requirements	Performance, efficiency, test methods
IEC 62040-4	Uninterruptible Power Systems – Environmental Aspects	Environmental requirements
IEC 60950-1 / 62368-1	Safety of Information Technology Equipment	Equipment safety
IEC 61000-4 Series	Electromagnetic Compatibility – Testing and Measurement Techniques	Immunity and emissions

Standard	Title	Application
IEEE 519	Harmonic Control in Electrical Power Systems	Harmonic distortion limits
IEEE 446	Recommended Practice for Emergency and Standby Power Systems	Industrial/commercial applications
IEEE 1100	Recommended Practice for Powering and Grounding Electronic Equipment	Power quality and grounding
Telecommunications Standards		
GR-63-CORE	NEBS Requirements: Physical Protection	Environmental (if applicable)
GR-1089-CORE	NEBS Requirements: EMC and Electrical Safety	EMC (if applicable)
Industry Best Practices		
Eaton	UPS Application Guide	Installation and configuration
Schneider Electric	UPS Handbook	Design and selection
Vertiv	Power and Thermal Management Guide	Battery and thermal management

1.3 SUBMITTALS

The Contractor shall submit the following documents for review and approval prior to procurement and installation:

a) UPS System Data Sheets:

- Manufacturer's technical specifications for the UPS model offered.
- Efficiency curves at various load levels.
- Output voltage regulation and harmonic distortion specifications.
- Overload and short-circuit characteristics.
- Acoustic noise levels (dB) at full load.
- Cooling requirements and airflow diagrams.
- Dimensions and weight (with and without batteries).
- Color finish and enclosure rating.

b) Battery System Submittals:

- Battery type, capacity (Ah), quantity, and configuration (series/parallel).
- Battery manufacturer and model number.
- Battery life expectancy (cycles and years) at operating temperature.
- Discharge curves at various load levels.
- Recharge time to 90% capacity after full discharge.
- Battery management system (BMS) specifications (if lithium-ion).
- Safety certifications (UL, IEC, etc.).
- Battery cabinet dimensions, ventilation requirements, and weight.

c) System Architecture and Coordination:

- Single-line diagram showing UPS input, output, bypass, and distribution.
- Coordination study with upstream and downstream protective devices.
- Load analysis confirming UPS capacity sizing.
- Run-time calculations at full load and actual load.
- Floor plan showing UPS and battery cabinet placement, including clearance requirements.
- Thermal management plan (cooling and ventilation).

d) Remote Monitoring and Control:

- SNMP card datasheet and supported MIBs.
- Web interface screenshots.
- Alarm and trap configuration details.
- Integration with the overall RCMS (if applicable).

e) Installation and Commissioning:

- Installation instructions and mounting details.
- Cable termination details (input, output, battery, control).
- Commissioning test procedures.
- Factory test reports (if available).
- Site acceptance test (SAT) plan.

f) Operation and Maintenance Manuals:

- User manual for normal operation (soft in USB & hard copy).
- Maintenance manual with schedules, procedures, and troubleshooting guides (soft in USB & hard copy).
- Battery maintenance and replacement guidelines.

- Spare parts list (minimum 5-year recommended).

PART 2 – PRODUCTS

2.1 UPS SYSTEM – GENERAL REQUIREMENTS

2.1.1 Type and Topology

- **Type:** Double-conversion online (VFI – Voltage and Frequency Independent) per IEC 62040-3.
- **Output waveform:** Pure sine wave with <3% total harmonic distortion (THD) for linear loads; <5% for non-linear loads.
- **Transfer time:** Zero (0) milliseconds for normal operation (battery mode).
- **Bypass:** Automatic static bypass and manual maintenance bypass.
- **Redundancy:** N+1 redundancy, ensuring no single point of failure for critical loads associated with CNS/ATC operations.

2.1.2 Operating Modes

Mode	Description	Transition
Normal (On-Line)	Inverter supplies conditioned power; battery float charged	Continuous
Battery	Inverter draws from battery; utility fails or out of tolerance	Zero transfer time
Bypass (Automatic)	Load transfers to utility via static bypass; UPS fault or overload	<2 ms
Bypass (Manual)	Load transferred to utility via maintenance bypass; UPS maintenance	Seamless (make-before-break)

2.1.3 Input Specifications

Parameter	Requirement
Nominal voltage	230 V (single-phase) or 400 V (three-phase) as required
Voltage tolerance	±10% (without battery discharge)
Frequency	50 Hz ±5%
Power factor	≥0.99 at full load
Current THD	≤5% at full load
Input protection	Circuit breaker with magnetic/thermal trip

2.1.4 Output Specifications

Parameter	Requirement
Nominal voltage	230 V (single-phase)
Voltage regulation	±1% static; ±5% transient (load step 0-100%)
Frequency	50 Hz ±0.1% (inverter mode); ±5% (bypass mode)
Output power factor	≥0.9 (leading or lagging)
Overload capability	125% for 10 minutes; 150% for 60 seconds (on-line mode)
Crest factor	≥3:1
Efficiency	>93% at full load; >90% at 50% load (on-line mode)
THD (output)	<3% for linear loads; <5% for non-linear loads

2.1.5 Environmental and Physical Requirements

Parameter	Requirement
Operating temperature	–20°C to 40°C (full performance); derate above 40°C
Storage temperature	–20°C to 60°C
Relative humidity	0% to 95% (non-condensing)
Altitude	Up to 2230 m (AMSL) without derating; derate 1% per 100 m above
Acoustic noise	≤55 dBA at 1 m (in normal operation)
Enclosure rating	IP20 minimum for indoor equipment rooms; IP31 for areas with potential dust
Color	RAL 7035 (light grey) or as per site standard
Cooling	Forced air with redundant fans (or as per manufacturer standard)

2.2 UPS SYSTEM – SIZING AND CAPACITY

The Contractor shall perform a detailed load analysis for each location to determine the appropriate UPS capacity. Minimum recommended capacities:

Location	Minimum Recommended Capacity	Notes
ATC Tower	5 kVA – 10 kVA	Powers 6 remote controllers, monitors, AMHS terminal, small network equipment
Radio Equipment Room	10 kVA – 20 kVA	Powers VHF/UHF/HF radios (10+ units), DVLS servers (2), RCMS, network switches (3+), DC rectifier
Fire Station	3 kVA – 5 kVA	Powers 3 compact controllers, radio(s), associated equipment

Final capacities shall be confirmed during detailed design based on actual equipment loads.

2.3 BATTERY SYSTEM

2.3.1 General Requirements

Parameter	Requirement
Backup runtime	Minimum 2 hours at full rated load
Battery type	Lithium Iron Phosphate (LiFePO ₄) with integrated BMS or equivalent
Design life	Lithium: 10-15 years at 20°C ambient
Charging method	Temperature-compensated, three-stage (bulk, absorption, float)
Recharge time	≤8 hours to 90% capacity after full discharge
Protection	Overcurrent, overvoltage, undervoltage, overtemperature, short circuit

2.3.2 Lithium Battery Requirements (Preferred)

- **Chemistry:** Lithium Iron Phosphate (LiFePO₄) – preferred for safety and thermal stability.
- **Battery Management System (BMS):** Integrated with cell voltage balancing, overcharge protection, over-discharge protection, short circuit protection, temperature monitoring, communication (CAN bus, RS485, or Modbus) to UPS.
- **Enclosure:** Metal housing with flame-retardant materials.
- **Safety Certifications:** UL 1973, IEC 62619, or equivalent.

Acceptable Manufacturers: Eaton (xStorage), Schneider Electric (Lithium Battery Systems), Vertiv (Lithium-Ion Battery Cabinets), Tesla (Powerwall), BYD, Deutsche Power or equivalent meeting Clause 1.6.

2.3.3 Battery Cabinets

- **Type:** Dedicated battery cabinet(s) matching UPS form factor (tower or rack).
- **Construction:** Heavy-gauge steel, powder-coated finish.
- **Ventilation:** Passive or forced ventilation as required.
- **Access:** Lockable front door with viewing window.
- **Cabling:** Pre-wired with appropriate DC circuit breakers or fuses.

2.3.4 VRLA Battery Requirements (Not to be used)

- **Construction:** Sealed, maintenance-free, with recombination technology.
- **Case:** Flame-retardant (UL94 V-0) ABS.
- **Terminals:** Heavy-duty, corrosion-resistant.
- **Interconnections:** Copper busbars or insulated cables with compression lugs.
- **Safety:** Pressure relief valves, spark arrestors.

Acceptable Manufacturers (Not to be Used):

- **Energys** (Genesis, PowerSafe)
- **C&D Technologies**
- **Trojan**
- **Exide** (industrial division)
- **GS Yuasa**
- **Or equivalent** meeting specification requirements as per Clause 1.6 of Division 1 General Requirements.

2.4 MAINTENANCE BYPASS

2.4.1 Manual Maintenance Bypass (MMB)

Each UPS shall be equipped with an integral or external manual maintenance bypass switch to allow complete isolation of the UPS for maintenance without interrupting power to the load.

Requirement	Detail
Configuration	Make-before-break (closed transition) to prevent load interruption
Switching mechanism	Rotary switch with clear position indication (UPS / Bypass / Test)
Lockout/Tagout	Provisions for padlocking in maintenance position

Requirement	Detail
Indicators	LED or mechanical indicators for bypass status
Enclosure	IP20 minimum, with clear labelling

2.5 MONITORING AND COMMUNICATIONS

2.5.1 SNMP/Web Interface

Each UPS shall be equipped with a communication card providing:

- **Protocols:** SNMPv1/v2c/v3, HTTP/HTTPS, Modbus TCP, and email alerting.
- **Features:** Remote monitoring of all UPS parameters, shutdown coordination, event logging, firmware upgrade capability.
- **Compatibility:** Shall integrate with the overall RCMS system via SNMP traps.

2.5.2 Dry Contacts

Minimum four (4) programmable dry contact outputs for remote alarm indication: mains failure, battery low, UPS fault, bypass active.

2.5.3 Display

- **Type:** LCD or color touch-screen, backlit, multi-language support (English).
- **Information:** Mimic diagram, voltage/current readings, load percentage, battery runtime, alarm status, event log.
- **Controls:** Menu navigation for configuration and diagnostics.

2.6 FORM FACTOR AND MOUNTING

Location	Preferred Form Factor	Mounting
ATC Tower	Tower or rack-mount	Free-standing or in equipment rack
Radio Equipment Room	Rack-mount (19-inch)	In 19-inch equipment cabinet
Fire Station	Tower or wall-mount	Compact, space-saving

The UPS units shall be supplied with all necessary mounting hardware, brackets, and interconnecting cables.

2.7 ACCEPTABLE MANUFACTURERS

Acceptable manufacturers include Eaton (9PX, 9SX, 93E, 93PM), Schneider Electric (Galaxy VS, Galaxy VL, Smart-UPS On-Line), Vertiv (Liebert PSI, Liebert GXT, Liebert EXM), Socomec (Modulys, Netys, Masters), Riello (Master MHE, Master HE, Sentinel), Deutsche Power or equivalent meeting Clause 1.6.

PART 3 – EXECUTION

3.1 SITE PREPARATION

3.1.1 Environmental Conditions

- UPS and battery rooms shall be clean, dry, and well-ventilated.
- Ambient temperature shall be maintained within the manufacturer's specified range (typically 20°C to 25°C for optimal battery life).
- The Contractor shall coordinate with the HVAC contractor to ensure adequate cooling and ventilation.

3.1.2 Floor Loading

- Floor loading capacity shall be verified prior to installation.
- Equipment pads or bases shall be provided as required to distribute weight.

3.1.3 Access and Clearance

- Minimum clearances shall be maintained per manufacturer's requirements (typically 1 m front, 0.5 m rear and sides).
- Access for battery replacement and maintenance shall be provided.

3.2 INSTALLATION

3.2.1 UPS Mounting

- UPS units shall be installed plumb and level.
- Rack-mounted units shall be secured with appropriate rails and fasteners.
- Tower units shall be placed on stable, vibration-damped surfaces.

3.2.2 Battery Cabinet Installation

- Battery cabinets shall be placed adjacent to or near the UPS.
- DC cabling between UPS and batteries shall be sized for the maximum discharge current with a voltage drop $\leq 1\%$.
- Battery cabinets shall be secured to the floor or rack as required.

3.2.3 Cabling and Termination

Circuit	Conductor Requirements
Input (Utility)	Copper, sized for 125% of UPS input current, with appropriate overcurrent protection
Output (Load)	Copper, sized for output current, with distribution to load panels or direct equipment
DC (Battery)	Flexible copper, sized for maximum discharge current, with DC-rated breakers or fuses

Circuit	Conductor Requirements
Control and Monitoring	Shielded twisted pair or CAT6 as required

- All terminations shall be torqued to manufacturer specifications.
- Cables shall be labelled at both ends with circuit identification.

3.2.4 Ventilation

- For lithium batteries, follow manufacturer's thermal management requirements (may require forced cooling).

3.3 BATTERY MANAGEMENT AND SAFETY

3.3.1 Battery Handling

- Batteries shall be handled with appropriate PPE (gloves, eye protection).
- Lifting equipment shall be used for heavy battery modules.
- Batteries shall be stored in a cool, dry location prior to installation.

3.3.2 Battery Connections

- Connections shall be clean, tight, and protected against corrosion.
- Anti-oxidation compound shall be applied to terminals.
- Torque values shall be recorded and submitted.

3.3.3 Battery Labelling

- Each battery string shall be labelled with voltage, polarity, and installation date.
- Warning labels shall be placed on battery cabinets indicating electrical and chemical hazard.

3.4 COMMISSIONING AND TESTING

3.4.1 Pre-Energization Checks

- Verify all connections are tight and correct.
- Measure insulation resistance ($\geq 1 \text{ M}\Omega$) between conductors and ground.
- Verify proper grounding of UPS chassis and battery cabinets.
- Check battery interconnections for correct polarity.

3.4.2 Functional Tests

- Energize UPS in bypass mode; verify input voltages.
- Transfer to normal (on-line) mode; verify output voltage and frequency.
- Perform battery discharge test at 50% and 100% load for 5 minutes; verify runtime and transfer.

- Test static bypass operation (simulate UPS fault).
- Test manual maintenance bypass (simulate UPS maintenance).
- Verify all alarms and indicators function.

3.4.3 Load Bank Test

- If the actual load is less than 50% of UPS capacity, a load bank shall be used to test at 100% load for 15 minutes.
- Load bank shall be provided by the Contractor.

3.4.4 Remote Monitoring Test

- Verify SNMP card configuration and connectivity.
- Generate test traps and verify receipt by RCMS.
- Test email alerts.

3.5 DOCUMENTATION

The Contractor shall provide upon completion:

- As-installed single-line diagrams.
- UPS and battery cabinet layout drawings (as-built).
- Commissioning test report with all recorded measurements.
- Battery installation date and expected end-of-life.
- Maintenance schedule.
- Operation and maintenance manuals (3 hard copies + digital).

PART 4 – SPECIAL PROVISIONS FOR CNS APPLICATIONS

4.1 CRITICAL LOAD CONSIDERATIONS

4.1.1 Inrush Current Capability

The UPS shall handle the inrush current of all connected equipment simultaneously, including radio transmitters switching to transmit mode, DVLS servers spinning up disks, and switch/router power-on surges.

4.1.2 Noise and Interference

The UPS shall not introduce conducted or radiated interference that affects radio receiver sensitivity. The Contractor shall provide EMC test reports confirming compliance with IEC 62040-2.

4.1.3 Synchronization

UPS output shall be synchronized with utility frequency (50 Hz) in normal mode to facilitate seamless bypass transfer.

4.2 COORDINATION WITH GENERATOR (IF APPLICABLE)

If the site is equipped with a standby generator, the UPS input shall be coordinated with the generator to ensure compatibility: the UPS shall accept generator power without nuisance transfers, and input current THD shall not cause generator instability.

4.3 INTEGRATION WITH RCMS

The SNMP interface shall provide to the RCMS system: UPS status (On-Line, Battery, Bypass, Fault), load percentage, battery runtime remaining, temperature (internal), and active alarms. The Contractor shall configure SNMP traps to align with RCMS alarm categories.

PART 5 – WARRANTY AND MAINTENANCE

5.1 WARRANTY

- **UPS Unit:** Minimum 2 years (24 months) from Final Acceptance.
- **Lithium Batteries:** Minimum 5 years (60 months) or as per manufacturer's warranty. The Contractor shall provide warranty support including on-site replacement of defective components.

5.2 SPARE PARTS

The Contractor shall supply a recommended list of spare parts for 5 years of operation, including input/output fuses, cooling fans, communication card, and battery replacement set (or battery module for lithium).

DIVISION 04 – POWER CONDITIONING AND BATTERY SYSTEMS (DC POWER)

PART 1 – GENERAL

1.1 SCOPE

This section specifies the requirements for a complete, high-reliability DC power system with lithium battery backup for all CNS equipment at Skardu Airport. The DC system shall provide continuous, regulated between range of 19.2 to 32 V or better range DC power to:

- VHF Air Band Multimode Transceivers (18 units: 10 operational + 4 spare + 4 OCC)
- UHF Air Band Digital Transceivers (4 units)
- HF Transceivers (2 x 1 kW main/standby + 2 x 125 W monitoring)
- Digital Voice Logging System (DVLS) servers
- Network switches and other IP-based equipment
- Any other equipment requiring DC power as required by design

The DC power system shall be designed for mission-critical availability, incorporating N+1 rectifier redundancy, lithium iron phosphate (LiFePO₄) battery technology with integrated BMS, and comprehensive remote monitoring capabilities, providing a minimum of **2 hours of backup power** at full load.

1.2 REFERENCES

The DC power system shall comply with the latest editions of IEC 62368-1, IEC 61000 Series, IEC 62040, IEC 60204-1, IEC 60950-22, ETSI EN 300 132-2, ETSI EN 300 119, GR-1089-CORE, GR-63-CORE, IEC 62619, IEC 62620, UL 1973, UN 38.3, and industry best practices (Eltek, Vertiv, Delta).

1.3 SUBMITTALS

The Contractor shall submit rectifier system data sheets, battery system submittals, distribution panel submittals, monitoring and control submittals, system design documentation (SLD, load analysis, battery capacity calculation, voltage drop calculations, grounding diagram, thermal calculations), installation and commissioning plans, and operation/maintenance manuals.

PART 2 – PRODUCTS

2.1 DC POWER SYSTEM – GENERAL REQUIREMENTS

2.1.1 System Voltage and Capacity

Parameter	Requirement
Nominal voltage	48 VDC (nominal)
Voltage range	Between range of 19.2 to 32 VDC or wider range adjustable
System capacity	Sufficient for full load plus battery charging (minimum 8 kW or as calculated)

Parameter	Requirement
Load capacity	To be calculated based on all connected CNS equipment

The system shall be designed with a minimum **20% growth margin** for future expansion.

2.1.2 Rectifier System

Parameter	Requirement
Topology	High-frequency switching, power factor corrected (PFC)
Rectifier modules	Modular, hot-swappable, N+1 redundancy
Module capacity	1 kW – 3 kW per module (as required)
Number of modules	N+1 where N = number required for full load + battery recharge
Input voltage	230 V AC (single-phase) or 400 V AC (three-phase) $\pm 20\%$, 50 Hz $\pm 5\%$
Input power factor	≥ 0.99 at full load
Input current THD	$\leq 5\%$ at full load (EN 61000-3-2 compliant)
Output voltage	Adjustable 42 – 58 V DC; factory set to 53.5 V (float) for LiFePO_4
Output voltage regulation	$\pm 1\%$ (static); $\pm 5\%$ (transient 0-100% load)
Output ripple	≤ 50 mV peak-to-peak (with battery connected)
Efficiency	$\geq 94\%$ at 50% load; $\geq 92\%$ at 100% load
Cooling	Forced air with redundant fans (or natural convection for low-power modules)
Operating temperature	-20°C to $+65^\circ\text{C}$ (full output up to 55°C , derated above)
MTBF	$\geq 200,000$ hours per module (Telcordia SR-332)
Protection	Overvoltage, overcurrent, overtemperature, reverse polarity
Hot-swap capability	Modules replaceable without interrupting DC output

Acceptable Rectifier Manufacturers: Eltek (Flatpack series), Vertiv (NetSure series), Delta (DPR series), ABB (MNS series), Schneider Electric, or equivalent meeting Clause 1.6.

2.1.3 Battery System – Lithium Iron Phosphate (LiFePO_4)

Parameter	Requirement
Battery chemistry	Lithium Iron Phosphate (LiFePO ₄)
Nominal voltage	48 V (typically 15 or 16 cells in series)
Capacity	Calculated to achieve ≥2 hours at full load, with 20% safety margin
Cycle life	≥3,000 cycles at 80% depth of discharge (DoD)
Calendar life	≥10 years at 25°C
Operating temperature	–10°C to +50°C (charge); –20°C to +60°C (discharge)
Energy density	≥100 Wh/kg (typical)
Safety certifications	IEC 62619, UL 1973, UN 38.3

Battery Management System (BMS) Requirements:

- Cell monitoring (individual cell voltage, temperature, balancing)
- State of Charge (SoC) accurate within ±3%
- State of Health (SoH) estimation
- Overvoltage, undervoltage, overcurrent, short circuit, overtemperature protection
- Communication: CAN bus, Modbus RTU/TCP, or RS485
- Active or passive cell balancing
- DC-rated contactors for disconnection
- Dry contacts for critical alarms

Battery Cabinet Requirements:

- Enclosure: Heavy-gauge steel, powder-coated (RAL 7035)
- Mounting: 19-inch rack-mount or free-standing
- Ventilation: Passive or forced with temperature-controlled fans
- Access: Lockable front door with viewing window
- Internal cabling: Pre-wired with DC-rated cables and connectors
- Safety: Fire-retardant materials, emergency disconnect

Acceptable Lithium Battery Manufacturers: Eltek (SmartPack), Vertiv, Delta, Eaton (xStorage), BYD, CATL, Deutsche Power (Lithium Battery System) or equivalent meeting Clause 1.6.

2.1.4 DC Distribution Panel

Parameter	Requirement
Panel type	19-inch rack-mount or wall-mount as per site
Busbars	Copper, tinned, sized for total load
Main input	From rectifier/battery bus (with main DC circuit breaker)
Output circuits	Minimum 20 outputs (expandable)
Protection	Each output with fuse (T-Lag) or DC-rated circuit breaker
Fuse/breaker rating	As calculated per load (6A, 10A, 16A, 20A, 32A)
Indication	LED indicator for each fuse/breaker (open/closed)
Monitoring	Voltage and current measurement per circuit (optional)
Labelling	Clear labelling for each output (equipment designation)

Typical distribution panel configuration (to be confirmed as per design):

Output	Equipment	Protection
1-10	VHF Transceivers (18 units) + 4 spare + 4 OCC	10A fuse each
11-14	UHF Transceivers (4 units)	15A fuse each
15-18	HF Transceivers (2 x 1 KW + 2 x 125W monitoring)	20A fuse each or as required
19-20	DVLS Servers (2 units + accessories)	10A fuse each
21-23	Network Switches (3 units)	5A fuse each
24-30	Spare (for future expansion)	10A fuse each

2.2 SYSTEM CONTROLLER AND MONITORING

Parameter	Requirement
Controller type	Microprocessor-based, with local LCD display
Display	LCD or touch-screen showing system voltage, load current, battery current, temperature, alarms, event log

Parameter	Requirement
Control functions	Rectifier module control, battery charge profile, alarm thresholds
Data logging	Minimum 1,000 events (time-stamped)
Remote monitoring	SNMPv1/v2c/v3, Modbus TCP, web interface
Dry contacts	Minimum 8 programmable outputs for remote alarms
Alarm categories	Mains failure, rectifier fault, battery low, battery disconnect, distribution fault, overtemperature, etc.
Integration	Shall interface with RCMS via SNMP traps

Acceptable Manufacturers: Eltek (SmartPack2, MiniPack), Vertiv (NetSure NCU, SCC), Delta, Schneider Electric, or equivalent.

2.3 BATTERY CHARGING PROFILE

The rectifier system shall be configured with a charge profile optimized for LiFePO_4 :

Stage	Voltage	Current	End Condition
Bulk	Constant current	Up to rectifier capacity (C/2 to C/5)	Reaches absorption voltage
Absorption	56.8 V (3.55 V per cell)	Tapering current	Current drops to C/20 or timer
Float	53.5 V (3.35 V per cell)	Minimal	Continuous

PART 3 – EXECUTION

3.1 SITE PREPARATION

- Install DC system in a clean, dry, well-ventilated equipment room. Ambient temperature maintained within 15°C to 30°C for optimal battery life.
- Verify floor loading capacity; provide equipment pads or leveling feet; seismic bracing if required.
- Maintain minimum clearances: 1 m front, 0.5 m rear and sides.

3.2 INSTALLATION

- Install DC system cabinets (rectifier, battery, distribution) in a dedicated battery cabinet as required. Secure cabinets to building structure.

- Install rectifier modules in designated slots; blanking panels for empty slots.
- AC input connections with appropriately sized cables, protected by dedicated circuit breaker.
- Install battery modules per manufacturer's instructions; series/parallel connections with pre-cut insulated cables and compression lugs; torque to manufacturer specifications; verify polarity before connection; connect BMS to system controller.
- Install distribution panel adjacent to rectifier cabinet; size DC feeder cables from rectifier/battery bus to distribution panel for voltage drop $\leq 1\%$; route output circuits to individual equipment; color-code cables: red (+), black (-), green/yellow (PE); label at both ends.
- Ground DC system; system positive (+) may be grounded as per manufacturer's recommendation; all cabinets bonded to Main Grounding Busbar (MGB) with 25 mm² conductor.
- Route DC cables in separate conduits or trays from AC power and data cables; bundle with Velcro ties; maintain minimum bend radius.

3.3 COMMISSIONING AND TESTING

Pre-Energization Checks: Verify all connections tight and correct; measure insulation resistance (≥ 1 M Ω); verify correct polarity; verify BMS communication; verify safety warnings/labels.

Rectifier Functional Tests: Energize AC input; verify input voltage and phase rotation; verify rectifier modules power up; measure output voltage and adjust to float setting (53.5 V); verify load sharing between modules ($\pm 5\%$); hot-swap test: remove one module, verify remaining modules support load.

Battery Tests: Connect battery after verifying voltage and polarity; verify battery accepts charge current; battery discharge test: disconnect AC input, verify load transfers to battery without interruption; measure discharge time at full load (or load bank) for 15 minutes minimum; extrapolate to 2 hours; verify BMS alarms; recharge test: verify recharge to 90% within manufacturer's specified time.

Distribution Tests: Verify each output circuit has correct voltage at equipment termination; verify fuse/breaker coordination; measure voltage drop at farthest load ($\leq 5\%$ from rectifier output).

Monitoring and Alarm Tests: Verify SNMP communication with RCMS; generate test alarms (simulate mains failure, rectifier failure, battery low) and verify traps received; test dry contact outputs.

3.4 DOCUMENTATION

Provide as-installed single-line diagrams, cabinet layout drawings (as-built), commissioning test report, battery installation date/serial numbers/expected end-of-life, BMS configuration settings, operation/maintenance manuals (3 hard copies + digital), spare parts list with manufacturer part numbers.

PART 4 – SYSTEM OPERATION AND MAINTENANCE

4.1 NORMAL OPERATION

Under normal conditions, rectifiers supply load while maintaining batteries at float voltage. System controller continuously monitors and logs system parameters. Alarms reported locally and via SNMP to RCMS.

4.2 BATTERY OPERATION

Upon AC mains failure, batteries supply load without interruption. BMS monitors battery condition and disconnects battery if any cell reaches critical limits. When AC returns, rectifiers recharge batteries with programmed profile.

4.3 MAINTENANCE

Monthly: Inspect for loose connections, dust accumulation, abnormal noises; verify display readings against measured values; check alarm logs.

Semi-Annual: Test battery discharge (10 minutes or as per manufacturer) and document capacity; clean air filters and fans; verify fuses/breakers operational; test remote monitoring and alarm functions.

Battery Replacement: Replace lithium batteries when SoH falls below 80% or at end of calendar life (10 years). Contractor shall provide replacement battery modules as required during warranty period.

PART 5 – SPARE PARTS AND WARRANTY

5.1 SPARE PARTS

Contractor shall supply for 5 years of operation:

- Rectifier module (same as installed): 1 unit (10% of installed modules, minimum 1)
- System controller (if hot-swappable): 1 unit
- DC distribution fuses (all ratings): 2 of each rating
- Cooling fans (rectifier cabinet): 2 units
- BMS communication module: 1 unit

5.2 WARRANTY

- Rectifier modules and system controller: 24 months (2 years) from Final Acceptance.
- Lithium batteries: 60 months (5 years) or as per manufacturer's warranty, whichever longer.
- Distribution panel and components: 24 months (2 years) from Final Acceptance.

DIVISION 05– GROUNDING AND BONDING

PART 1 – GENERAL

1.1 SCOPE

This section specifies the complete grounding and lightning protection system for all CNS equipment, antennas, AWOS sensors, and associated infrastructure at Skardu Airport. The system shall provide a low-impedance path for fault currents, lightning strikes, and electromagnetic interference, ensuring personnel safety, equipment protection, and reliable operation of sensitive electronic systems.

1.2 REFERENCES

The system shall comply with IEC 62305 (all parts), IEC 61000-4-5, ITU-T K.56, ITU-T K.66, IEEE 1100, IEEE 142, ANSI/TIA-607-B, NFPA 780.

1.3 SUBMITTALS

- Grounding system design drawings (single-line, layout, details)
- Earth resistance test reports
- Surge protection coordination study (SPD selection and placement)
- As-built documentation (drawings, test results)
- Material certificates (rods, conductors, connectors, SPDs)
- Installation photographs (critical connections)

PART 2 – PRODUCTS

2.1 EARTH ELECTRODE SYSTEM (GROUNDING PITS)

2.1.1 Earth Rods

- **Type:** Copper-bonded steel (minimum 250 µm copper coating)
- **Length:** 2.5 m or 3.0 m (drive length) or as per design
- **Diameter:** 16 mm (minimum)
- **Tensile strength:** $\geq 600 \text{ N/mm}^2$
- **Connection:** Threaded couplings for extension (if required)

2.1.2 Earth Enhancement Compound

- **Type:** High-conductivity cementitious or bentonite-based compound
- **Resistivity:** $\leq 0.5 \text{ } \Omega \cdot \text{m}$ (when mixed)
- **Corrosion:** Non-corrosive to copper and steel
- **Environment:** Non-toxic, environmentally safe

2.1.3 Inspection Pits

- **Material:** Polymer concrete or heavy-duty PVC (UV-stabilized)

- **Cover:** Lockable, load-bearing (Class D or higher for vehicle traffic)
- **Internal busbar:** Tinned copper, 50 mm × 6 mm, with connection points
- **Dimensions:** Minimum 300 mm × 300 mm × 300 mm (depth)

2.1.4 Main Grounding Busbar (MGB)

- **Material:** Tinned copper
- **Dimensions:** 300 mm × 50 mm × 10 mm (minimum)
- **Mounting:** Insulated standoffs (ceramic or plastic)
- **Connection points:** Drilled and tapped (M10 or M12) at 50 mm intervals
- **Location:** In equipment room, accessible for maintenance

2.2 GROUNDING CONDUCTORS

Application	Material	Size	Insulation
Main earthing conductor	Bare tinned copper	95 mm ²	–
Equipment cabinet bonding	Insulated (green/yellow)	25 mm ²	PVC, 600 V
Antenna mast bonding	Bare tinned copper	50 mm ²	–
Surge arrestor bonding	Insulated (green/yellow)	16 mm ²	PVC, 600 V
Cable tray bonding	Bare or insulated	16 mm ²	As required
Building structural bonding	Bare tinned copper	50 mm ²	–

Connection Method: Exothermic welding (preferred) or compression lugs with anti-oxidation compound.

2.3 SURGE PROTECTIVE DEVICES (SPDs)

2.3.1 AC Power SPDs

- **Type 1 (10/350 µs):** Main distribution panel – $I_{max} \geq 25$ kA, $U_p \leq 2.5$ kV
- **Type 2 (8/20 µs):** Sub-panels, UPS outputs – $I_{max} \geq 20$ kA, $U_p \leq 1.5$ kV
- **Type 3:** Equipment outlets (optional) – $I_{max} \geq 10$ kA, $U_p \leq 1.0$ kV

2.3.2 RF Coaxial SPDs

- **Type:** Gas discharge tube (GDT) with $\lambda/4$ or broadband design
- **Frequency bands:** VHF (118-137 MHz), UHF (225-400 MHz), HF (2-30 MHz)
- **Insertion loss:** ≤ 0.2 dB
- **VSWR:** $\leq 1.2:1$

- **Discharge current:** ≥ 20 kA (8/20 μ s)
- **Connectors:** N-type female (or 7/16 DIN for high power)

2.3.3 Ethernet SPDs

- **Type:** Shielded, CAT6a rated
- **Configuration:** 4-pair protection with gas tube and diodes
- **Data rate:** Up to 1 GbE (10 GbE optional)
- **Insertion loss:** ≤ 0.5 dB
- **Clamping voltage:** ≤ 100 V
- **Connectors:** RJ-45 shielded (in/out)

2.3.4 Signal/Control SPDs

- Multi-pair or single-pair as required; voltage 12 V, 24 V, 48 V as required.

Acceptable SPD Manufacturers: DEHN, Phoenix Contact, Citel, Raycap, Eaton Bussmann, or equivalent meeting Clause 1.6.

PART 3 – EXECUTION

3.1 EARTH ELECTRODE SYSTEM

- Construct a minimum of **two (2) earth pits** (or more as required to achieve ≤ 1 Ω).
- Drive earth rods vertically to depth of 2.5-3.0 m; where bedrock encountered within 1.5 m, install horizontal radial electrodes in trenches (10 m minimum per radial, 600 mm depth, 95 mm² bare tinned copper).
- Backfill with earth enhancement compound mixed with water to form slurry.
- Install inspection pit with busbar; connect earth rods and radials to busbar.
- Interconnect all earth pits with 95 mm² bare tinned copper conductor (ring earth) buried at 600 mm depth around building perimeter.
- Connect to building structural steel at multiple points.

3.2 MAIN GROUNDING BUSBAR (MGB)

- Mount MGB in equipment room on insulated standoffs.
- Connect main earthing conductor from earth pits to MGB using exothermic welding.
- Connect building structural steel to MGB (multiple points).
- Bond all equipment cabinets to MGB with dedicated 25 mm² conductors.

3.3 EQUIPMENT GROUNDING

- Each equipment cabinet bonded to MGB with 25 mm² green/yellow conductor.
- Cabinets in a row interconnected with ground bus (copper bar) along the row.

- Doors and removable panels bonded to frame with flexible copper braid (6 mm² minimum).
- Each radio, server, switch, and other electronic device bonded via chassis ground screw to cabinet ground bus.

3.4 ANTENNA GROUNDING

- Each antenna mast bonded to grounding system with 50 mm² bare tinned copper conductor at base using exothermic welding or compression lug. If mast exceeds 20 m height, intermediate bonding at 20 m intervals.
- Surge arrestors installed at point where coaxial cable enters building, mounted on grounded plate or directly to MGB; grounding conductor ≤0.5 m.
- Coaxial shield grounding kit installed at antenna mast base; shield grounding conductor 16 mm² minimum.

3.5 SURGE PROTECTION COORDINATION

AC Power:

- Main distribution panel: Type 1 SPD, parallel connection, conductor length ≤0.5 m
- UPS Input/Output: Type 2 SPD at UPS bypass panel
- Equipment cabinets: Type 2 SPD in cabinet or adjacent panel

RF Coaxial: SPD at building entry for each antenna feeder, grounded to MGB with 16 mm² conductor.

Ethernet: SPD at building entry for external cables; SPD at equipment cabinet for internal runs (optional).

Signal/Control: SPD at building entry for external sensors (AWOS, etc.).

3.6 TESTING

3.6.1 Earth Resistance Measurement

- **Method:** Fall-of-potential (three-point) per IEEE 81
- **Test equipment:** Calibrated earth tester
- **Acceptance:** ≤1 Ω (after interconnection of all pits and ring earth)
- Test shall be performed during dry season for worst-case condition.

3.6.2 Continuity Testing

- Test all bonding connections between MGB and cabinets, masts, structural steel.
- **Acceptance:** Resistance ≤0.1 Ω

3.6.3 SPD Verification

- Verify SPD status indicators (green = normal).
- Document SPD models, locations, and ratings.

3.6.4 Insulation Resistance

- Test between grounding system and live conductors (disconnected).
- **Acceptance:** $\geq 1 \text{ M}\Omega$

PART 4 – DOCUMENTATION

The Contractor shall provide:

- As-built grounding drawings (earth pit locations, interconnections, MGB, mast bonding, surge arrestor locations)
- Earth resistance test report (including weather conditions, date, time)
- Continuity test results
- SPD coordination study
- SPD data sheets and installation instructions
- Photographs of critical connections (exothermic welds, MGB, surge arrestors)

DIVISION 06 – COMMUNICATIONS (STRUCTURED CABLING)

PART 1 – GENERAL

1.1 SCOPE

This section specifies the complete structured cabling infrastructure required to support all CNS equipment at Skardu Airport, including:

- **Data Cabling:** Shielded twisted-pair cabling for Ethernet/IP connectivity supporting ED-137 VoIP, SNMP monitoring, and network management.
- **RF Cabling:** Low-loss coaxial cabling for VHF, UHF, and HF antenna systems.
- **Fiber Optic Cabling:** For backbone connections and long-distance runs where required.

The structured cabling system shall provide a reliable, high-performance, and scalable infrastructure supporting dual LAN redundancy (LAN A and LAN B) for all critical CNS equipment, VoIP communication per EUROCAE ED-137C, remote monitoring and control via SNMP, and future expansion.

1.2 REFERENCES

Cabling shall comply with ISO/IEC 11801 (all parts), IEC 60793, IEC 60794, TIA/EIA-568-C, TIA/EIA-569-C, TIA/EIA-606-B, TIA/EIA-607-B, IEC 61196, IEC 60169, and industry best practices (BICSI TDMM).

1.3 SUBMITTALS

- Cable test reports (manufacturer's data sheets, Fluke or equivalent test results for copper and fiber, VSWR test results for RF, insertion loss, return loss)
- As-built cable routing diagrams (floor plans, cable schedules, riser diagrams, patch panel layouts)
- Labelling schedule (naming convention, sample labels, implementation plan)
- Installation documentation (pulling plans, conduit fill calculations, bonding/grounding diagrams)
- Test equipment calibration certificates

PART 2 – PRODUCTS

2.1 DATA CABLING – COPPER

2.1.1 Cable Type and Performance

- **Cable type:** Shielded twisted pair (FTP or S/FTP)
- **Category:** Category 6A (or higher) for future 10 GbE support
- **Conductor:** 23 AWG solid bare copper (not copper-clad aluminium)
- **Shielding:** Overall foil shield with drain wire (FTP) or braid + foil (S/FTP)
- **Impedance:** 100 Ω $\pm$ 15%

- **Frequency rating:** 500 MHz minimum
- **Fire rating:** LSZH (Low Smoke Zero Halogen) per IEC 61034 for indoor installations; plenum rating as required.
- Meets ISO/IEC 11801 Class EA and TIA/EIA-568-C Category 6A.

2.1.2 Connectors and Hardware

- **Connector type:** RJ-45, shielded, Category 6A rated
- **Termination:** 110 IDC or tool-less
- **Shielding continuity:** 360° shielding coverage
- **Patch panels:** 19-inch rack-mount, 1HU, with shielded RJ-45 ports, grounding bar
- **Outlets:** Shielded modular jacks with faceplates or surface-mount boxes
- **Patch cords:** Shielded, Category 6A, factory-terminated, various lengths

2.1.3 Acceptable Manufacturers

CommScope (SYSTIMAX GigaSPEED X10D), Panduit (TX6A 10Gig Shielded), Belden (10GXS), Siemon, R&M, or equivalent meeting Clause 1.6. All components from same manufacturer.

2.2 RF CABLING – COAXIAL (50 Ω)

2.2.1 Coaxial Cable – VHF/UHF (118-400 MHz)

- **Type:** Low-loss foam dielectric, 50 Ω
- **Size:** ½" (12.7 mm) diameter nominal
- **Inner conductor:** Copper or copper-clad aluminium (solid or corrugated)
- **Dielectric:** Foam polyethylene
- **Outer conductor:** Corrugated copper tube
- **Jacket:** Black polyethylene, UV-resistant, flame-retardant
- **Attenuation:** ≤ 2.7 dB/100 m at 150 MHz; ≤ 4.8 dB/100 m at 450 MHz
- **Velocity of propagation:** $\geq 88\%$
- **Capacitance:** ≤ 76 pF/m
- **Impedance:** 50 $\Omega \pm 2 \Omega$

Acceptable Manufacturers: Andrew/CommScope (LDF4-50A Helix), RFS (Cellflex ½"), Times Microwave (LMR-600), Huber+Suhner (SUCONET), or equivalent.

2.2.2 Coaxial Cable – HF (2-30 MHz)

- Low-loss, 50 Ω , ½" or ⅞" depending on length; attenuation ≤ 1.0 dB/100 m at 30 MHz; UV-resistant jacket suitable for outdoor burial.

2.2.3 RF Connectors

- **N-type:** VHF/UHF antennas, combiners, filters; female and male, 50 Ω , weatherproof, silver or gold plated.
- **7/16 DIN:** High-power applications; 50 Ω , low PIM, weatherproof.
- **BNC (if required):** Test points, internal rack connections; 50 Ω , crimp or clamp.

Requirements: soldered or crimped center conductor; corrosion-resistant plating; weatherproofing with self-amalgamating tape and heat-shrink; low PIM (≤ -150 dBc) for UHF applications.

2.2.4 RF Surge Arrestors

- Gas discharge tube, coaxial in-line, frequency range DC to 3 GHz, insertion loss ≤ 0.2 dB, VSWR $\leq 1.2:1$, discharge current ≥ 20 kA (8/20 μ s), N-type female/female, integral ground lug.

Acceptable Manufacturers: PolyPhaser (Transtector), Huber+Suhner, Andrew/CommScope, Citel, or equivalent.

2.3 FIBER OPTIC CABLING

2.3.1 Fiber Optic Cable

- **Type:** Single-mode, OS2
- **Core/Cladding:** 9/125 μ m
- **Attenuation:** ≤ 0.4 dB/km at 1310 nm and 1550 nm
- **Wavelengths:** 1310 nm and 1550 nm (bidirectional)
- **Construction:** Loose tube or tight-buffered; aramid yarn strength members; LSZH jacket (indoor), UV-resistant (outdoor); fire rating OFNP or OFNR.

2.3.2 Fiber Optic Connectors and Hardware

- **Connector type:** LC duplex (small form factor)
- **Connector polish:** UPC
- **Insertion loss:** ≤ 0.3 dB per connection
- **Return loss:** ≥ 55 dB
- **Patch panels:** 19-inch rack-mount, with splice trays and pigtails
- **Patch cords:** LC to LC, OS2, various lengths

2.3.3 Acceptable Manufacturers

CommScope (SYSTIMAX LazrSPEED), Panduit (Opticom Fiber System), Corning (SMF-28e), Belden, or equivalent.

PART 3 – EXECUTION

3.1 GENERAL INSTALLATION REQUIREMENTS

- Coordinate with other trades; conduits and cable trays installed prior to finishing work.
- Cable segregation:

Cable Type	Separation from Power Cables
Data (shielded Cat6a)	≥150 mm (6 inches)
Fiber optic	≥50 mm (2 inches)
RF coaxial	≥300 mm (12 inches)
Power cables	Grouped separately

Crossing at 90° unavoidable.

- Cable trays; conduits sized for 40% fill (power) or 50% fill (data/fiber); sweeps for fiber and RF.
- Minimum bend radii:

Cable Type	Installation	Permanent
Cat6a shielded	4 × cable diameter	4 × diameter
Fiber optic	20 × diameter	10 × diameter
½" coaxial	250 mm (10 inches)	125 mm (5 inches)

3.2 DATA CABLING INSTALLATION

- Maximum pulling tension 110 N (25 lbf); use lubricant; no kinks; support at ≤1.5 m.
- Termination: strip jacket exposing shield drain wire; bond shield 360° per manufacturer; maintain pair twists to within 13 mm of termination point.
- Patch panels in racks with proper labelling; service loops; Velcro ties.

3.3 RF CABLING INSTALLATION

- Antenna feeder installation: clamps every 1.5-2 m; drip loops before building entry; fire-stop and weather seal at entry.
- Connector installation per manufacturer's instructions; weatherproofing: clean/dry, anti-oxidation compound, self-amalgamating tape (50% overlap), PVC electrical tape, heat-shrink.
- Grounding and bonding: coaxial cables grounded at antenna mast and building entry; surge arrestors at point of entry; grounding kits at intervals not exceeding 50 m.

3.4 FIBER OPTIC CABLING INSTALLATION

- Maximum pulling tension ≤600 N; pulling eye or swivel; no sharp edges; maintain bend radius.
- Termination and splicing: precision cleave; fusion splicing for permanent connections (splice loss ≤0.1 dB); pigtails spliced to cable fibers in splice trays; connectors field-terminated with epoxy/polish.

- Fiber patch panels: 19-inch rack-mount with dust caps; patch cords routed with slack management.

3.5 LABELING

- Naming convention consistent with TIA/EIA-606-B (example: ER-XX for equipment room, C-XX for cabinet, PP-XX for patch panel, P-XX for port, SRC-DEST-XXX for cable).
- Label types: wrap-around self-laminating for cables; laminated plastic for patch panels and faceplates; permanent marker or heat-shrink for fiber splice trays.
- Placement: within 50 mm of termination both ends; clearly visible on patch panel face; above/beside outlets; on conduits within 1 m of ends and every 10 m.

3.6 TESTING

3.6.1 Copper Data Cabling

- **Test Equipment:** Fluke DSX-5000 or equivalent (calibrated)
- **Tests:** Wire map, length, insertion loss, NEXT, PSNEXT, ACRF, PSACRF, return loss, propagation delay, delay skew
- **Acceptance:** Pass all Category 6A requirements per ISO/IEC 11801
- **Documentation:** Electronic test results for each link

3.6.2 RF Cabling Testing

Test	Method	Acceptance Criteria
Continuity	Visual and multimeter	All conductors continuous
VSWR	Network analyzer (e.g., Anritsu Site Master)	$\leq 1.5:1$ across operating frequency
Insertion loss	Network analyzer	$\leq$ calculated budget
DC resistance	Multimeter	$\leq$ calculated per manufacturer

3.6.3 Fiber Optic Testing

Test	Method	Acceptance Criteria
Continuity	Visual fault locator (VFL)	Visible light through fiber
Insertion loss	Optical loss test set (OLTS)	$\leq$ calculated budget (connectors + splice loss)
OTDR trace	Optical time domain reflectometer	Trace for each fiber; no excessive loss events
Polarity	Light source and power meter	Correct transmit/receive pairing

PART 4 – INTEGRATION WITH CNS SYSTEMS

4.1 DUAL LAN REDUNDANCY

- Each equipment cabinet shall have separate cable bundles for LAN A and LAN B.
- LAN A and LAN B cables routed via separate pathways where possible.
- Redundant switches (LAN A and LAN B) cabled to all dual-homed equipment.
- Cables labelled to clearly indicate LAN A or LAN B.

4.2 RF CABLING FOR ANTENNA SYSTEMS

System	Antennas	Cable Runs	Connectors
VHF (5 channels)	6 antennas	Radio room to antenna masts	N-type
UHF (2 channels)	2 antennas	Radio room to antenna masts	N-type
HF & HF (Monitoring)	3 broadband antennas	Radio room to antenna masts	N-type or 7/16 DIN

4.3 EMC CONSIDERATIONS

- Shielded Cat6a cabling bonded to equipment cabinet ground at one end only.
- Coaxial cable shields grounded at building entry and antenna mast.
- All metallic cable trays bonded to grounding system.

PART 5 – DOCUMENTATION AND CLOSEOUT

- As-built cable routing diagrams (CAD format)
- Updated cable schedule with actual lengths and termination points
- Patch panel mapping (port to cable to equipment)
- Test results (electronic format with summary report)
- Label schedule and photos of labelled cables

Spare parts for 5 years: Cat6a shielded patch cords (20), RJ-45 shielded connectors (50), N-type connectors (20 each), coaxial surge arrestors (2), fiber optic patch cords LC-LC (10), cable labels (5 rolls).

DIVISION 07 – VHF AIR BAND RADIO SYSTEM

PART 1 – GENERAL

1.1 SCOPE

Complete VHF air band communication system for ATC Tower and Fire Station, including eighteen (18) VHF/AM 50 W multimode transceivers configured in five (5) main/standby pairs (10 operational + 4 spare + 4 OCC), cable tray 1x1 feet from top roof of ATC tower to ECR, separate earth pit for CNS equipment, seven (7) VHF band pass dual cavity filter/combiners (5+2 spare), eight (8) VHF omnidirectional antennas (6+2 spare), all associated RF cabling, connectors, surge arrestors, mounting hardware, antenna masts, grounding, and lightning protection.

System fully compliant with ICAO Annex 10, EUROCAE ED-137C, and ETSI EN 300 676. Supports voice (AM) and data (ACARS, VDL Mode 2), fully integrated with VoIP-based ATC network.

1.2 REFERENCES

ICAO Annex 10 Volume V, EUROCAE ED-137C, ETSI EN 300 676, EUROCAE ED-138, IEC 62368-1, IEC 61000-4 Series.

1.3 SUBMITTALS

- Technical data sheets (transceivers, combiners, antennas)
- Factory test reports (power output, sensitivity, modulation, VoIP latency, combiner VSWR/insertion loss, antenna patterns)
- Configuration details (frequency assignment plan, output power settings, SNMPv3 configuration, ED-137C VoIP parameters)
- System design documentation (block diagram, rack layout, antenna mast details, grounding scheme)
- Installation and testing plans

PART 2 – PRODUCTS

2.1 VHF/AM MULTIMODE TRANSCEIVER

Parameter	Requirement
Frequency Range	118 – 137 MHz
Channel Spacing	25 kHz / 8.33 kHz (selectable per channel)
Modulation Modes	AM voice, ACARS (AM-MSK), VDL Mode 2 (D8PSK) – all licenses included
Output Power	1 – 50 W adjustable
Receiver Sensitivity	≤ -107 dBm for 6 dB SINAD (AM)

Parameter	Requirement
Adjacent Channel Selectivity	≥ 60 dB at ± 25 kHz
Spurious Emissions	≤ -60 dBc (ETSI EN 300 676)
VoIP Interface	Two independent 10/100/1000Base-T Ethernet ports (LAN A / LAN B); ED-137C compliant RTP streams; up to 4 simultaneous VCS streams + 4 recorder streams; G.711 μ -law/A-law and G.729 (optional); adaptive jitter buffer
Remote Management	SNMPv3 (MD5/SHA, DES/AES); full MIB; built-in web server
Local Interface	OLED graphical display, menu buttons; built-in speaker; local configuration
Redundancy	Main/standby ready; external control inputs (e.g., ACU-3); separate analog control at ATC tower for VoIP failure
BITE	Continuous monitoring of power output, VSWR, voltages, currents, temperatures, synthesizer lock, RSSI/AGC; alarms via SNMP and front panel
MTBF	$\geq 50,000$ hours
Start-Up Time	≤ 10 seconds
VoIP Round Trip Delay	≤ 30 ms (optimized mode)
Power Supply	Integrated, between 19.2 to 32 V DC (nominal) or wider range & 230 V AC; redundant power input
Physical	3U, 19-inch rack-mountable; depth ≤ 350 mm; weight ≤ 15 kg
Environmental	Operating -20°C to $+55^{\circ}\text{C}$; storage -40°C to $+70^{\circ}\text{C}$; humidity 0-95% non-condensing
Compliance	ICAO Annex 10, ETSI EN 300 676, ED-137C, RoHS, REACH

Accessories per transceiver: rack-mounting kit, AC power cord or DC connector, RJ-45 Ethernet cables (2), documentation (hard copy and USB), configuration software with life-time licenses.

Acceptable Manufacturers: Jotron, Rohde & Schwarz, or equivalent meeting Clause 1.6.

2.2 VHF BAND PASS DUAL CAVITY FILTER / COMBINER

Parameter	Requirement
Type	2-channel, dual cavity band pass filter combiner
Frequency Range	118 – 137 MHz (field-tunable or factory-tuned)
Number of Inputs	2 (Main/Standby per channel)
Number of Outputs	1 (to antenna)
Isolation	≥70 dB between input ports, Filter Selectivity (dB) at mid band with I.L.: 2 dB @ $f_0 \pm 1\% f_0 > 44$
Insertion Loss	≤3.5 dB per path
Power Handling	≥50 W per input (continuous)
VSWR	≤1.3:1 (input and output)
Impedance	50 Ω
Connectors	N-type female (or 7/16 DIN)
Rack Mount	4HU, 19-inch, front tuning access
Temperature Stability	Frequency drift ≤2 ppm/°C

Acceptable Manufacturers: Polomarconi, Sinclair Technologies, Telemac, or equivalent.

2.3 VHF (AM) OMNIDIRECTIONAL ANTENNA

Parameter	Requirement
Type	½ dipole, omnidirectional
Frequency Range	118 – 137 MHz
Gain	≥2 dBi (nominal)
VSWR	≤1.5:1 across full range
Polarization	Vertical
Impedance	50 Ω
Power Handling	≥100 W (continuous)
Lightning Protection	Integrated DC ground or surge arrestor

Parameter	Requirement
Connector	N-type female (weatherproofed)
Mounting	Mast or tower mounting kit (1.5-2.5 m diameter)
Material	Aluminium or stainless-steel elements, UV-resistant radome
Environmental	IP65, corrosion-resistant, wind loading ≥ 180 km/h, temperature -30°C to $+60^{\circ}\text{C}$

Accessories: mounting bracket with U-bolts, surge arrestor, grounding kit, installation hardware.

Acceptable Manufacturers: Kathrein, Procom, Sinclair Technologies, Polomarconi, or equivalent.

2.4 LOW-LOSS COAXIAL CABLE ($\frac{1}{2}$ " foam dielectric, 50 Ω as specified in 2.2.1)

PART 3 – EXECUTION

3.1 INSTALLATION

- Transceivers mounted in 19-inch cabinets in radio equipment room as main/standby pairs.
- Each transceiver connected to LAN A, LAN B, DC power, combiner input, and ACU-3 (if external).
- Combiners mounted in same or adjacent cabinets; output to antenna feeder cable.
- Antenna masts installed at approved locations (tower roof or dedicated mast); bonded to grounding system; oriented for vertical polarization and aligned for maximum coverage.
- Surge arrestors at building entry (coaxial surge arrestor on grounded plate, bonded to MGB).
- Coaxial feeders secured with weatherproof clamps at ≤ 1.5 m intervals; maintain bend radius; label at both ends.
- Antenna mast bonded to building grounding system with 50 mm² copper; coaxial shield grounding kits at mast base and building entry; surge arrestors bonded to MGB with 16 mm² minimum conductor; ground connections exothermically welded or crimped.

3.2 TESTING

3.2.1 Factory Acceptance Test (FAT)

- Full functional test of each transceiver (all modes)
- VoIP latency and ED-137C compliance
- SNMPv3 configuration and trap generation
- Combiner VSWR and insertion loss measurement
- Antenna pattern verification (if available)

3.2.2 Site Acceptance Test (SAT)

Test	Method	Acceptance Criteria
Visual Inspection	Walk-down	Installed per drawings; labels in place; cabling neat
Continuity	Multimeter	All cables continuous
VSWR	Network analyzer (Site Master)	$\leq 1.5:1$ at operating frequency
Transmitter Power	Power meter / spectrum analyzer	Within ± 1 dB of programmed power
Receiver Sensitivity	Signal generator	≤ -107 dBm for 6 dB SINAD
VoIP Connectivity	Packet analyzer	ED-137C RTP streams; dual LAN redundancy verified
SNMP Communication	SNMP manager	All traps received; configuration changes successful
Redundancy Test	Manual failover	Main fails; standby takes over without interruption
BITE Alarms	Simulate fault	Alarms reported locally and via SNMP

3.3 DOCUMENTATION

- As-built cabling diagrams (RF and data)
- VSWR test reports for all antenna feeders
- Transmitter power and frequency records
- Configuration files for all transceivers (backup)
- SNMPv3 user and trap configuration
- Antenna mast grounding resistance test results

DIVISON 08 – UHF AIR BAND RADIO SYSTEM

PART 1 – GENERAL

1.1 SCOPE

Complete UHF air band communication system for ATC Tower, including four (4) UHF/AM digital transceivers configured in two (2) main/standby pairs, two (2) UHF dual cavity band pass filters, three (3) UHF omnidirectional antennas, and all associated RF cabling, connectors, surge arrestors, and mounting hardware.

1.2 REFERENCES

ICAO Annex 10 Volume V, EUROCAE ED-137C, ETSI EN 302 617, IEC 62368-1.

1.3 SUBMITTALS

Transceiver data sheets, filter performance curves (insertion loss, rejection), antenna radiation patterns and gain measurements, splitter insertion loss and isolation measurements, factory test reports, system block diagram and redundancy architecture.

PART 2 – PRODUCTS

2.1 UHF/AM DIGITAL TRANSCEIVER

Parameter	Requirement
Frequency Range	225 – 400 MHz (continuous coverage)
Channel Spacing	25 kHz
Modulation	AM (voice)
Output Power	Programmable 1 – 50 W in 1 W steps
VoIP Interface	Two independent 10/100/1000Base-T Ethernet ports (LAN A/B), ED-137C compliant RTP streams
Remote Management	SNMPv3
Front Panel	OLED display, local controls, status indicators
Redundancy	Main/standby ready; external changeover unit (e.g., ACU-3)
BITE	Continuous monitoring of power output, VSWR, temperatures, synthesizer lock
Duty Cycle	100% continuous @ ambient temperature <40°C
Protection	Over-temperature, over-voltage, high VSWR (automatic power reduction)

Parameter	Requirement
Power Supply	19.0–32.0 VDC (nominal) or wider range and 230VAC.
Physical	3U, 19-inch rack-mountable
Environmental	–20°C to +55°C operating

Acceptable Manufacturers: Jotron, Rohde & Schwarz, or equivalent.

2.2 UHF/AM DIGITAL RECEIVER

Parameter	Requirement
Frequency Range	225 – 400 MHz
Modulation	AM
Sensitivity	≤ -107 dBm for 6 dB SINAD
Adjacent Channel Selectivity	≥ 60 dB at ± 25 kHz
Spurious Response Rejection	≥ 80 dB
Audio Output	Balanced analog (600 Ω) and VoIP (RTP streams)
VoIP Interface	Two Ethernet ports, ED-137C compliant
Remote Management	SNMPv3
Squelch	Adjustable (noise-based and level-based)
Power Supply	Between range of 19.2 to 32 V DC or wider range (nominal)
Physical	3U, 19-inch rack-mountable

Acceptable Manufacturers: Jotron, Rohde & Schwarz, or equivalent.

2.3 UHF DUAL CAVITY BAND PASS FILTER

- Function: Band-pass for transmitter combiner path; frequency 225-400 MHz (factory-tuned); insertion loss ≤ 1.5 dB per channel; rejection ≥ 60 dB at ± 5 MHz; power handling ≥ 50 W; VSWR $\leq 1.3:1$; impedance 50 Ω ; connectors N-type female; rack mount 4HU.

Acceptable Manufacturers: Polomarconi, Telewave, Tlemec, or equivalent.

2.4 UHF OMNIDIRECTIONAL ANTENNA

- Type: Dipole, omnidirectional; frequency 225-400 MHz; gain ≥ 2 dBi; VSWR $\leq 1.5:1$; vertical polarization; 50 Ω ; power handling ≥ 100 W; N-type female weatherproofed; mast mounting kit; surge arrestor in-line.

2.5 RF SPLITTER

- Passive 2-way, 50 Ω , 225-400 MHz; insertion loss ≤ 3.5 dB; isolation ≥ 20 dB; VSWR $\leq 1.3:1$; power handling ≥ 10 W; N-type female; 19-inch rack or cabinet mounting.

PART 3 – EXECUTION

3.1 INSTALLATION

- Transceivers configured as two main/standby pairs (Pair 1: TX1 Main + TX2 Standby; Pair 2: TX3 Main + TX4 Standby). Each main/standby pair connects to a dual cavity filter, then to a dedicated antenna.
- Both antennas physically separated to minimize desensitization; masts bonded to grounding system.
- Surge arrestors at building entry for all antenna feeders.
- All RF connections use $\frac{1}{2}$ " low-loss coaxial cable; connectors weatherproofed; cables labelled with channel identification.

3.2 TESTING

Test	Method	Acceptance Criteria
Transmitter Power	Power meter	Within ± 1 dB of programmed power
Receiver Sensitivity	Signal generator	≤ -107 dBm for 6 dB SINAD
VSWR (Antenna)	Network analyzer	$\leq 1.5:1$
Filter Insertion Loss	Network analyzer	≤ 1.5 dB
Splitter Isolation	Network analyzer	≥ 20 dB
VoIP Connectivity	Packet analyzer	ED-137C streams established
Redundancy	Simulated failure	Standby takes over without interruption

DIVISION 09 – HF COMMUNICATIONS SYSTEM

PART 1 – GENERAL

1.1 SCOPE

HF communication system for long-range backup communications, including two (2) HF transceivers with 1 kW output power, two (2) broadband HF antennas with automatic tuning units, and two (2) HF transceivers 125 watts for monitoring with broadband antenna.

1.2 REFERENCES

ICAO Annex 10 Volume V, ITU-R Recommendations, RTCA DO-186.

1.3 SUBMITTALS

Transceiver/receiver data sheets, antenna tuning unit specifications, antenna radiation patterns, factory test reports.

PART 2 – PRODUCTS

2.1 HF TRANSCEIVER (VoIP Supported)

Parameter	Requirement
Frequency Range	2 – 30 MHz (continuous, with ITU-assigned aeronautical bands)
Output Power	1 kW PEP (nominal)
Modulation	USB (J3E), AME, compatible with ATC voice
Receiver Sensitivity	≤ -110 dBm for 10 dB SINAD (USB)
Antenna	Broadband with automatic antenna tuning unit (ATU)
Remote Control	Ethernet (SNMP) and/or serial (RS-232/485); VoIP supported
Front Panel	LCD display with controls
Frequency Stability	± 1 ppm
Compliance	ICAO Annex 10, ITU-R
Power Supply	230 V AC or between range of 19.2 to 32 V DC or wider range
Environmental	0°C to 50°C operating

Accessories per transceiver: ATU, broadband antenna (e.g., log-periodic or whip), coaxial feeder, remote control cable (if applicable), 19-inch rack-mounting kit.

Acceptable Manufacturers: Rohde & Schwarz, Barrett Communications, Codan, JRC, Sunair, or equivalent.

2.2 HF RECEIVER (VoIP Supported)

Parameter	Requirement
Frequency Range	2 – 30 MHz
Modulation	USB, AME
Sensitivity	≤ -110 dBm for 10 dB SINAD
Antenna	Dedicated receiving antenna (whip or broadband)
Audio Output	Balanced analog (600 Ω) and speaker
Remote Control	Ethernet/SNMP (optional); VoIP supported
Power Supply	230 V AC or between range of 19.2 to 32 V DC or wider range

Acceptable Manufacturers: Rohde & Schwarz, Barrett Communications, Icom, or equivalent.

PART 3 – EXECUTION

3.1 INSTALLATION

- HF transceivers and receivers installed in radio equipment room.
- ATU near antenna base (weatherproof enclosure).
- Broadband antennas on dedicated masts with proper grounding and lightning protection.
- Coaxial feeders low-loss, 50 Ω , with surge arrestors at building entry.
- All outdoor equipment rated IP65 minimum.

3.2 TESTING

Test	Method	Acceptance Criteria
Transmitter Power	Power meter	1 kW ± 0.5 dB
Receiver Sensitivity	Signal generator	≤ -110 dBm
Antenna Tuning	ATU auto-tune	VSWR $\leq 1.5:1$ at tuned frequency
VoIP/Control	Ethernet test	Remote control and audio established

DIVISION 10 – RADIO REMOTE CONTROLLERS

PART 1 – GENERAL

1.1 SCOPE

VoIP-based radio remote controllers for ATC tower and fire station, providing operators with full control of VHF, UHF, and HF radios over the IP network.

1.2 REFERENCES

EUROCAE ED-137C, SNMPv3, ITU-T G.711/G.729.

1.3 SUBMITTALS

Controller data sheets, UPS specifications, headset/microphone specifications, integration details with VCS (if applicable).

PART 2 – PRODUCTS

2.1 RADIO REMOTE CONTROLLER SYSTEM (supporting VHF, UHF, HF, hot lines, SIP telephone lines)

Component	Requirement
Display Unit (JDU)	>10" touch-screen, 800×480 resolution minimum, capacitive or resistive (aviation glove compatible), swivel arm or desktop mount
Microphone Interface (JMI-111A or equivalent)	Desktop unit with integrated loudspeaker (≥ 2 W), XLR or aviation microphone connector, volume control knob, PTT button
Foot Pedal	Heavy-duty PTT footswitch with 2.5 m cable, momentary contact
Headset	Aviation headset with noise-canceling electret microphone, 10-pin push-pull connector, over-ear or on-ear, impedance 150-300 Ω
UPS	2000 VA online double-conversion UPS with external battery pack providing ≥ 3 hours backup at full controller load
VoIP	ED-137C compliant; two independent 10/100/1000Base-T Ethernet ports for LAN A / LAN B redundancy
Control Capacity	Minimum 10 radio control, hot lines, telephone lines (digital/analog) or SIP phone
Security	Hardened Linux OS; SNMPv3 monitoring; role-based access control
Audio Codecs	G.711 μ -law/A-law, G.729 optional
Power	12 - 32 VDC or wider range or 230 V AC via UPS
Physical	Desktop or ATC console fitting

Acceptable Manufacturers: Jotron, Rohde & Schwarz, or equivalent meeting Clause 1.6.

PART 3 – EXECUTION

3.1 INSTALLATION

- Six main controllers at six ATC console positions, integrated into console furniture.
- Three compact controllers at fire station and other designated positions.
- Each controller connected to both LAN A and LAN B switches with shielded Cat6a cables.
- UPS units for ATC tower controllers installed under desks or in dedicated racks, with power distribution to each controller.

3.2 TESTING

Test	Method	Acceptance Criteria
Controller boot	Power-on	Boots to operational state within 60 seconds
LAN redundancy	Remove LAN A	Continues operation on LAN B
PTT function	Simulate transmit	Radio transmits; audio quality clear
Audio quality	Test call	No distortion, latency ≤ 30 ms
UPS backup	Remove mains	Controllers remain operational for ≥ 3 hours

DIVISION 11 – REMOTE CONTROL AND MONITORING SYSTEM (RCMS)

PART 1 – GENERAL

1.1 SCOPE

RCMS software and hardware for centralized management of all radios (VHF, UHF, HF) and associated equipment.

1.2 SUBMITTALS

Software installation media and license certificates, user manuals (operator and administrator), SNMP MIB files, hardware specifications for workstation and laptop.

PART 2 – PRODUCTS

2.1 RCMS SOFTWARE SUITE (1 Lot)

Component	Requirement
RCMS Server	Linux-based / Windows based OS; SNMPv1/v2c/v3 management; alarm logging with historical database; event archiving; multi-site support
Client Licenses	Minimum 5 concurrent operator clients with life-time license
Device Licenses	50 devices (each radio counts as one device)
Workstation	Industrial PC: Intel Core i7 (13th Gen or equivalent), 16 GB RAM, 1 TB SSD (NVMe), Windows 11 Pro, 24" LCD monitor, keyboard, mouse
Laptop	Same specification, portable (Quantity 2)
Features	Real-time status (PTT, squelch, alarms); remote configuration (frequency, power, squelch); BITE monitoring; historical reporting; remote audio monitoring; SNMP trap forwarding

2.2 RCMS CAPABILITIES

Function	Description
System Status	Frequency, serial numbers, firmware, timers; operational status; live PTT and squelch; active alarms; voltages, currents, temperatures; monitoring and controlling all transceiver features
System BITE	Power output, reflected power, VSWR; analogue line levels; modulation levels; RSSI and AGC; frequency accuracy

Function	Description
Maintenance	Activation of test tones; remote audio monitoring; calibration adjustments; event log viewing
Configuration	Frequency, offset, channel space; modulation parameters; audio and PTT sources; output power; squelch adjustments; VoIP parameters (codec, jitter buffer)
Reporting	Availability reports; alarm history; configuration change logs

PART 3 – EXECUTION

3.1 INSTALLATION

- RCMS server software installed on dedicated industrial PC in equipment room.
- RCMS workstation installed at ATC tower or administration area.
- All radios configured with SNMPv3 credentials; SNMP traps directed to RCMS server IP address.

3.2 TESTING

Test	Method	Acceptance Criteria
Server installation	Software load	Server boots, services running
Device discovery	SNMP scan	All 50 devices discovered and displayed
Real-time monitoring	Observe status	PTT, squelch, alarms update in real time
Remote configuration	Change frequency	Radio frequency changes successfully
Alarm generation	Simulate fault	Trap received, alarm displayed, logged
Report generation	Generate availability report	Report produced with correct data

DIVISION 12 – DIGITAL VOICE LOGGING SYSTEM (DVLS)

PART 1 – GENERAL

1.1 SCOPE

Dual redundant voice recording system for recording all ATC communications (VHF, UHF, HF, ambient microphones, telephone lines) with synchronized replay capability.

1.2 REFERENCES

EUROCAE ED-111, CAP670, ICAO Annex 10, EUROCAE ED-137C.

1.3 SUBMITTALS

Recorder server data sheets, storage capacity calculations, replay software specifications, NTP synchronization details, test procedures.

PART 2 – PRODUCTS

2.1 DUAL REDUNDANT 48-CHANNEL RECORDER (Ricochet equivalent) (1 Lot)

Parameter	Requirement
Architecture	Two independent recording servers (A and B) operating in parallel; no single point of failure; both record all sources simultaneously
Channel Capacity	Minimum 48 channels, each configurable for analog (balanced/unbalanced) or VoIP (ED-137C, RTP, SIP)
Analog Inputs	Balanced, 600 Ω , adjustable gain 0 to +20 dB
VoIP Recording	Passive recording of RTP streams; supports ED-137C metadata (PTT, squelch, channel ID)
Storage	RAID 5 or RAID 10 with hot-spare; minimum 31 days online storage at 15% activity per channel
Synchronization	NTP client; GPS optional; timestamp accuracy ≤ 1 ms
Replay Client	Web-based or standalone with synchronized replay of multiple channels, timeline navigation, bookmarking, export (audio files, impound, archive)
Offline Player	Standalone version for impounded files (Catch Offline equivalent)
Network	Dual 1 GbE ports per server for redundancy
Management	SNMP alarms; user access control (role-based); audit trail; event logging
Servers	Industrial rack-mount (2U), redundant power supplies, hot-swappable drives
NTP Clock	Meinberg or equivalent, with GPS antenna (optional)

Parameter	Requirement
Console	Keyboard, mouse, monitor for local access
Speakers	Powered speakers for replay audio

2.2 RECORDING SOURCES

Source Type	Quantity	Interface
VHF Radios	10	VoIP (RTP) and/or analog
UHF Transmitters	4	VoIP (RTP)
UHF Receivers	4	VoIP (RTP)
HF Transceivers	2	VoIP (RTP) or analog
HF Receivers	5	VoIP (RTP) or analog
Ambient Microphones	2	Analog (balanced)
Telephone Lines / Hot lines	4	SIP or analog

2.3 ACCEPTABLE MANUFACTURERS

Jotron, Exacom, Ascend/Redbox, Voxtronic, Rohde & Schwarz, or equivalent meeting Clause 1.6.

PART 3 – EXECUTION

3.1 INSTALLATION

- Servers mounted in recorder cabinet (dedicated 19-inch rack).
- Both servers connected to LAN A and LAN B for redundancy.
- Analog audio inputs terminated on Krone or equivalent patch panels.
- VoIP recording configured to passively capture RTP streams from network.
- NTP client synchronized to site master clock or GPS.
- Replay workstation installed in ATC tower or administration area.

3.2 TESTING

Test	Method	Acceptance Criteria
Channel configuration	Software setup	All 48 channels configured with correct source types

Test	Method	Acceptance Criteria
Recording verification	Speak/test tone on each source	Audio recorded on both servers
Synchronization	Replay same time on multiple channels	Audio aligned within 1 ms
Storage capacity	Monitor disk usage	Calculated capacity ≥ 31 days
Redundancy	Power off Server A	Server B continues recording without loss
Replay	Retrieve historical recording	Audio plays with correct time stamp
Export	Export audio file	File plays in standard media player
NTP sync	Check time stamps	Synchronized to NTP source

3.3 DOCUMENTATION

- Channel configuration table
- NTP synchronization configuration
- Replay user manual
- Maintenance procedures (backup, drive replacement)

DIVISION 13 – OPERATIONAL CRISIS CONTROL (OCC) ROOM EQUIPMENT

PART 1 – GENERAL

1.1 SCOPE

Supply, installation, testing, and commissioning of equipment for the Operational Crisis Control (OCC) Room at Skardu Airport, including dedicated communication systems: telephony (PABX), VHF AM mobile radios, VHF AM handheld radios, VHF FM handheld radios, and associated infrastructure. The OCC Room shall be located within the ATCT building as per approved layout.

1.2 RELATED SECTIONS

Voice Communications Systems, DVLS, (UPS), ATC Console Furniture, Electrical.

1.3 SUBMITTALS

- Equipment data sheets (PABX, radios, accessories)
- System architecture drawings (block diagram integration with airport PABX, PSTN, VCCS, recording)
- Installation drawings (OCC room layout, console, PABX rack, telephone/radio positions)
- Cable schedules
- Factory test reports
- Operation and maintenance manuals (including programming software)

1.4 QUALITY ASSURANCE

All equipment new, proven design. PABX system availability $\geq 99.98\%$ over 10 years. Equivalent products meet Clause 1.6.

PART 2 – PRODUCTS

2.1 OCC PRIVATE AUTOMATIC BRANCH EXCHANGE (PABX)

2.1.1 General

Digital communication system with stored program control, IP-enabled, dedicated to OCC Room.

2.1.2 System Capacity and Configuration

Parameter	Minimum Requirement
Analog subscribers	Up to 20 (expandable to 30)
Digital subscribers	Up to 20 (expandable to 30)
IP subscribers	Up to 30 (expandable to 45)
Digital operator consoles	Minimum 4
V.24 interfaces	Minimum 2

Parameter	Minimum Requirement
ISDN PRI (30 channels)	As specified in BOQ (minimum 1 PRI)
Direct Inward/Outward Dialing	On all PRI channels
Redundancy	Redundant power supply and processor cards

2.1.3 Technical Features

- Digital transmission: PCM A-law (ITU-T G.711, G.712)
- Time-out and release facilities
- Backup memory: non-volatile (Flash, EPROM), automatic reload within 1 minute
- Self-diagnostics with alarm output
- Traffic performance: non-blocking, ≥600 Erlang
- MTBF ≥10 years

2.1.4 Regulatory Compliance

EN 60950-1, EN 61000-6-2, EN 55024, ITU-T, ETSI, ISO.

2.1.5 Interfaces and Trunks

- Connections to Airport PABX: minimum 10 analog two-wire tie lines/trunks
- Connections to PSTN: minimum 20 analog trunk lines (or ISDN PRI)
- ISDN PRI two-way with DID/DOD, auto-plug-and-play

2.1.6 Attendant Consoles

- PC-based attendant console (1 unit) with handset/headset, PC (Core i5, 8 GB RAM, 256 GB SSD, Windows 10/11 Pro, Ethernet), software with telephone directory, extension status, call management
- Desktop digital console (1 unit) with DSS (minimum 40 keys)

2.1.7 Telephone Sets

- Normal telephone sets (analogue/digital): push-button, adjustable receive volume, with/without CLI, wall-mountable option.
- Executive telephone sets: intelligent voice terminals with hands-free intercom, auto-dial, multi-line backlit LCD, CLI display, status indication.

2.1.8 Call Logging and Accounting

- PC-based call logging (Core i7, 16 GB RAM, 1 TB SSD, Windows 11 Pro, Ethernet) with storage for ≥12 months call records including CLI.
- Call accounting software for reports by extension, trunk, cost center.

2.1.9 Power Supply and Battery Backup

- Primary power 230 V AC, 50 Hz.
- Battery backup: external maintenance-free dry batteries (lithium) with built-in charger; **no external stand-alone UPS**; ≥3 hours backup for PABX and connected telephone sets under full load.
- Provision for –48 V DC external supply.

2.1.10 Alarms and Test Facilities

- Audible/visual alarms for power failure, card failure, trunk failure, processor faults.
- Minimum three RS-232 (V.24) or Ethernet ports for local maintenance PC, traffic/call detail output, remote maintenance (modem supplied).
- Remote maintenance capability for programming, class of service changes, diagnostics.

2.1.11 Mechanical and Environmental

- Cabinet: free-standing, enclosed, IP42 minimum, vermin-proof, ventilated, lockable, cable entry from bottom.
- Rack-mountable sub-racks; front access preferred.
- Module identification: keyed edge connectors.
- Operating: +5°C to +40°C, 5-85% RH non-condensing.

2.1.12 Software Features (Minimum)

- Call handling: call detail, call tracing, CLI, closed numbering, connection restriction, cyclic/linear hunt groups, digit prefixing, distinctive ringing, hotline, multiple trunk groups, music on hold, night service, trunk access restrictions, extension relocate, timed disconnect, voice calling.
- Extension features: automatic callback, busy override, call forwarding/pickup/transfer, callback on no answer, do not disturb, DTMF dialing, emergency disconnect/override, executive/secretary, hold toggle, number redial, PIN/Follow me, release/disable call waiting, system speed dialing, 3- and 8-party conference, timed reminder.
- Attendant console features: assigning outgoing trunk calls, attendant busy override, call distribution by queue, call forwarding on no answer, concentrated answering for trunks, extending tie-trunks and internal calls, toggling between connections, night service options.

2.1.13 Acceptable Manufacturers

Alcatel-Lucent Enterprise (OmniPCX Enterprise), NEC (Univerge SV), Avaya (IP Office or CM), Siemens (Unify OpenScape Voice), Panasonic or equivalent meeting Clause 1.6.

2.2 VHF AM MOBILE RADIOS (Quantity: 5)

Parameter	Requirement
Frequency Range	118 – 137 MHz (aeronautical band)

Parameter	Requirement
Modulation	AM
Output Power	Adjustable 10 watts
Power Supply	12 V DC and 24 V DC (adaptable for vehicles)
Channels	Minimum 2 preset (121.500 MHz, 123.100 MHz); programmable up to 10
Receiver Sensitivity	≤ 6 dB μ V for 12 dB SINAD
Adjacent Channel Selectivity	≥ 70 dB
Spurious Response Rejection	≥ 70 dB
Intermodulation	≥ 60 dB
Frequency Stability	± 1.5 kHz
Environmental	Suitable for vehicle installation; operating -20°C to $+55^{\circ}\text{C}$
Accessories	Microphone, mounting bracket, power cable, antenna with cable (vehicle-type)

Acceptable Manufacturers: Jotron, Rohde & Schwarz, Icom (commercial grade), Motorola (with appropriate AM capability), or equivalent.

2.3 VHF AM HANDHELD RADIOTELEPHONES (Quantity: 6)

Parameter	Requirement
Frequency Range	118 – 137 MHz (aeronautical band)
Modulation	AM
Output Power	≥ 5 W (adjustable low/high)
Channels	Minimum 2 preset (121.500, 123.100 MHz); programmable up to 10
Battery	Built-in long-life rechargeable Li-ion pack
Receiver Sensitivity	≤ 6 dB μ V for 12 dB SINAD
Adjacent Channel Selectivity	≥ 70 dB

Parameter	Requirement
Spurious Response Rejection	≥ 70 dB
Intermodulation	≥ 60 dB
Audio Output	≥ 200 mW (<10% THD)
Water Resistance	Immersion to 1 m for 5 minutes (IP67 or equivalent)
Environmental	Operating -20°C to $+55^{\circ}\text{C}$; resistant to sea water, oil, sunlight
Accessories	Belt clip, antenna, drop-in charger, AC adapter, rechargeable battery pack

Acceptable Manufacturers: Icom (A-series), Vertex Standard, Motorola, or equivalent.

2.4 VHF FM HANDHELD RADIOTELEPHONES (Quantity: 10)

Parameter	Requirement
Frequency Range	146 – 174 MHz (VHF FM)
Modulation	FM
Output Power	≥ 5 W (adjustable high/low)
Channels	Minimum 99 programmable
Channel Spacing	5, 10, 12.5, 25 kHz selectable
Battery	Built-in long-life rechargeable Li-ion
Receiver Sensitivity	≤ 0.25 μV (12 dB SINAD)
Adjacent Channel Selectivity	≥ 60 dB (12.5 kHz) / ≥ 70 dB (25 kHz)
Intermodulation	≥ 60 dB
Audio Output	≥ 500 mW
Environmental	Operating -20°C to $+55^{\circ}\text{C}$; water resistant IP54 minimum
Accessories	Belt clip, antenna, drop-in charger, AC adapter, rechargeable battery pack

Acceptable Manufacturers: Motorola, Kenwood, Icom, Vertex Standard, Hytera, or equivalent.

2.5 INTEGRATION AND RECORDING

All communications equipment (PABX telephone lines, VHF AM mobile radios, VHF AM handheld radios when used in OCC, VHF FM handheld radios) shall be connected to the DVLS. Contractor shall provide all necessary interface cables, splitters, impedance matching devices. OCC PABX shall provide dedicated audio output port (balanced or VoIP) for each extension/trunk required to be recorded.

PART 3 – EXECUTION

3.1 INSTALLATION

- PABX main cabinet installed in OCC equipment room (as per layout), securely anchored, cables entered from bottom. MDF with Krone or similar connectors.
- Telephone sets installed at OCC workstations and other designated locations.
- Attendant console PCs installed on OCC console with neat cabling.
- VHF AM mobile radios: coordinate with vehicle supplier or install base station in OCC; for vehicle installation, provide complete kits including antennas and power cabling.
- Handheld chargers installed in OCC on dedicated charging rack powered from OCC UPS.
- All voice/data cabling .
- Trunk connections from PSTN and airport PABX terminated on PABX.
- Recording feeds run from PABX and radio equipment to DVLS termination point using shielded twisted pair or as required.
- PABX powered from dedicated AC source and its integral battery system (no external UPS). Radio equipment powered from OCC UPS.
- All equipment bonded to grounding system .

3.2 TESTING AND COMMISSIONING

3.2.1 Factory Acceptance Test (FAT)

Perform FAT for PABX at manufacturer's facility: all hardware/software features, redundancy, DID/DOD, call logging/accounting, battery backup and automatic reload, interface to trunk lines (simulated).

3.2.2 Site Acceptance Test (SAT)

Test	Method	Acceptance Criteria
PABX Basic Operation	Place internal/external calls	Dial tone, clear voice, successful connection
DID/DOD	Call from PSTN to OCC extension; call from OCC to PSTN	Call reaches correct extension; CLI displayed; outward call completed
Attendant Console	Answer, transfer, hold, conference	Features work per manufacturer specification

Test	Method	Acceptance Criteria
Call Logging	Generate call records	Records show CLI, duration, cost codes
Battery Backup	Remove AC power	PABX operates on battery; after AC restoration, system reloads within 1 minute
Radio Transmit/Receive	Test each radio unit	Audio clarity, output power within tolerance
Recording Interface	Make calls and radio transmissions	Audio recorded in DVLS with correct time-stamp and channel ID
System Integration	Coordinate with VCCS if used	OCC telephone lines accessible from VCCS if required

PART 4 – DOCUMENTATION

Contractor shall provide as-built wiring diagrams (extension numbers, trunk assignments, recording feeds), PABX configuration files (software backup), programming guides (user and administrator), radio programming software and frequency lists, operation manuals, maintenance logbook for OCC equipment.

DIVISION 14– METEOROLOGICAL SYSTEMS

SUB-DIVISION 14.1 – AUTOMATED WEATHER OBSERVING SYSTEM (AWOS) – CAT I

PART 1 – GENERAL

1.1 SCOPE

Complete Automated Weather Observing System (AWOS) for Skardu Airport meeting ICAO CAT I precision approach requirements for a single runway, providing real-time meteorological data for ATC, flight planning, and aeronautical information services. Scope includes Central Data Unit (CDU) with dual redundancy, full sensor suite, sensor masts, enclosures, communication interfaces, cabling, integration with ATC displays/AMHS/recording system, and complete grounding/lightning protection.

1.2 REFERENCES

ICAO Annex 3, ICAO Doc 9837, ICAO Doc 8896, WMO No. 8, WMO No. 49, ISO 28902, IEC 60945, FAA Order 6560.10C, EUROCAE ED-111.

1.3 SUBMITTALS

System design documentation (block diagram, sensor siting plan, mast/mounting details, cable routing, power distribution), sensor data sheets, CDU submittals (hardware, software, redundancy, communication protocols), factory test reports (sensor calibration, CDU validation), installation/calibration plans, acceptance test procedures.

PART 2 – PRODUCTS

2.1 AWOS CENTRAL DATA UNIT (CDU)

Parameter	Requirement
Architecture	Dual redundant configuration with automatic failover (or single unit with fully redundant internal components)
Processor	Industrial-grade, minimum 4 cores, 3.0 GHz or equivalent
Memory	Minimum 16 GB RAM
Storage	RAID 1 (mirrored) or RAID 5 with hot-spare; minimum 1 TB usable; capacity for ≥31 days raw sensor data, reports, logs
Data Processing	Real-time sensor acquisition (≤1 second update); data validation; meteorological calculations (QNH, QFE, dew point, density altitude, etc.)
Report Generation	METAR (hourly/on-demand), SPECI, trend reports (TREND), RVR for CAT I; automated voice output (optional), TDZ and MID etc
Reporting Formats	ICAO METAR code; IWXXM (XML); plain text for ATC displays
Time Synchronization	GPS receiver or NTP client; timestamp accuracy ≤1 second UTC

Parameter	Requirement
Interfaces	AMHS (serial/TCP/IP); ATC display systems (serial/TCP/IP/discrete); SNMP (remote monitoring); analogue/digital outputs for alarm indicators
User Interface	Graphical display of all sensors with real-time values, alarms, system status, configuration menus, data review/export
Alarms	Configurable thresholds for all sensors; equipment failure alarms; communication loss alarms; visual/audible (local)
Remote Monitoring	SNMPv3 for integration with RCMS; web-based interface (optional)
Physical	19-inch rack-mount (2U or 4U); front panel display or remote console
Power Supply	230 V AC with internal or external UPS; backup runtime ≥30 minutes (or as per site UPS)
Environmental	Operating –25°C to 50°C; humidity 0-95% non-condensing

Acceptable Manufacturers: Vaisala, Sutron, Campbell Scientific, All Weather Inc., or equivalent meeting Clause 1.6.

2.2 SENSOR SUITE

2.2.1 Wind Speed and Direction Sensor (Quantity: 1)

- 2D Ultrasonic (preferred) or mechanical (cup and vane); speed range 0-50 m/s, direction 0-360°; accuracy ± 0.5 m/s (≤ 20 m/s), $\pm 3\%$ (> 20 m/s), direction $\pm 3^\circ$ (minimum) ; resolution 0.1 m/s / 1° ; output RS-485/RS-232/analog 4-20 mA; integrated de-icing heating; IP66, operating –40°C to +60°C; mounted on mast at 10 m height (or per ICAO).

Acceptable Manufacturers: Vaisala, Campbell Scientific, Young, or equivalent.

2.2.2 Barometric Pressure Sensor (Quantity: 2 – Redundant)

- Digital barometer with internal temperature compensation; range 800-1100 hPa; accuracy ± 0.3 hPa; resolution 0.01 hPa; long-term stability ≤ 0.1 hPa/year; output RS-232/RS-485/SDI-12; operating –40°C to +60°C, IP65.

Acceptable Manufacturers: Vaisala, Paroscientific, Campbell Scientific, or equivalent.

2.2.3 Temperature and Humidity Sensor (Quantity: 1)

- Temperature range –40°C to +60°C, accuracy $\pm 0.2^\circ\text{C}$, resolution 0.1°C ; humidity range 0-100% RH, accuracy $\pm 2\%$ RH (0-90%), $\pm 3\%$ RH (90-100%); output RS-485/SDI-12; with radiation shield; IP65.

Acceptable Manufacturers: Vaisala (HMP155 with DTR503), Rotronic (HC2 series), Campbell Scientific (EE181), or equivalent.

2.2.4 Cloud Height Ceilometer (Quantity: 1 at TDZ)

- Laser-based LIDAR; range 0-7,500 ft (0-2,500 m) minimum; resolution 50 ft (15 m); accuracy ± 50 ft ($\leq 1,000$ ft), $\pm 10\%$ ($> 1,000$ ft); outputs cloud layers (up to 3), vertical visibility, backscatter profile; laser Class 1M or 3B with eye-safe interlocks; operating -40°C to $+60^{\circ}\text{C}$; IP66 with window de-icing; output RS-232/RS-485/Ethernet.

Acceptable Manufacturers: Vaisala, Campbell Scientific, Lufft, or equivalent.

2.2.5 Visibility / Runway Visual Range (RVR) Sensor (Quantity: 1 at TDZ)

- Forward scatter sensor (preferred for CAT I) or transmissometer; range 10-2,000 m (RVR) or 10- 20,000m visibility; accuracy $\pm 10\%$; scattering angle 40° - 45° ; output RS-232/RS-485/analog; integrated heating for optics; operating -40°C to $+60^{\circ}\text{C}$, IP66; MTBF $\geq 50,000$ hours; factory calibrated with field verification kit.

Acceptable Manufacturers: Vaisala, Biral, Lufft, or equivalent.

2.2.6 Present Weather Detector (Quantity: 1)

- Optical or combined optical/impact sensor; detectable phenomena: rain, snow, drizzle, freezing rain, hail, fog, mist, haze; output weather code (WMO table), precipitation type, intensity; precipitation rate range 0-99 mm/h; type accuracy $\geq 90\%$ correct; operating -40°C to $+60^{\circ}\text{C}$, IP66; output RS-232/RS-485/digital. (Function may be integrated into visibility sensor.)

Acceptable Manufacturers: Vaisala, Biral, Lufft, or equivalent.

2.2.7 Lightning Detector (Quantity: 1)

- Field mill or electrostatic detection; detection range ≥ 20 km radius; output Cloud and Cloud-to-Ground, Lightning within 30NM, More than 95% thunderstorm detection within 10NM (3 or more cloud discharge); dry contacts (alarm), RS-232, or Ethernet; adjustable distance thresholds (5,10,20 km); outdoor IP66, lightning-resistant; power 12/24 V DC or 230 V AC.

Acceptable Manufacturers: Vaisala, Biral, Campbell Scientific, or equivalent.

2.3 SENSOR MASTS AND ENCLOSURES

- Mast type: Galvanized steel, self-supporting or guyed, height as required (10 m for wind, 2-3 m for others)
- Foundation: Concrete footing with anchor bolts; grounding electrode integrated
- Enclosures: Weatherproof (IP65) for sensors with local electronics; lockable, with ventilation
- Cabling: Armored or conduit-protected; shielded twisted pair for data; proper termination in junction boxes

2.4 COMMUNICATION AND DATA INTERFACES

- Sensor to CDU: RS-485, RS-232, or Ethernet (Modbus, SDI-12, or proprietary)
- CDU to ATC displays: Serial (RS-232) or TCP/IP with defined data format
- CDU to AMHS: TCP/IP with IWXXM (XML) or legacy text formats
- CDU to RCMS: SNMPv3
- CDU to DVLS: Analog or VoIP for voice-generated weather broadcast (if required)

PART 3 – EXECUTION

3.1 SITING AND INSTALLATION

- Sensor siting per ICAO Annex 3, ICAO Doc 9837, and approved site-specific siting plan:

Sensor	Location	Height
Wind	Touchdown Zone (TDZ) – 300 m from threshold, 120 m from centerline	10 m AGL
Barometric Pressure	Near midpoint of runway, indoors if possible	1-2 m AGL
Temperature/Humidity	TDZ, away from buildings/paved surfaces	1.5-2 m AGL
Ceilometer	TDZ, clear view of sky, ± 300 m from threshold	Ground-based
Visibility/RVR	TDZ, 120 m from centerline, clear view of runway	2-5 m AGL
Lightning Detector	Clear of obstructions, away from power lines	On mast or roof

- Masts installed on concrete foundations designed for wind loading (≥ 180 km/h); each mast bonded to grounding system with 50 mm² copper conductor; surge arrestors at base of each mast for all cables.
- Sensor cables in rigid PVC conduits (Schedule 80) buried at minimum 600 mm depth with sand bedding and warning tape; cables entering buildings through surge arrestors and sealed against moisture; cable trays within buildings for exposed runs.
- CDU installed in equipment room (or ATC tower) in 19-inch rack or dedicated cabinet; redundant CDU (if separate) in separate location or same rack with independent power; CDU connected to airport network for AMHS and ATC display integration.

3.2 CALIBRATION AND VERIFICATION

- Factory calibration with traceability to national/international standards; certificates provided.
- Field verification:

Sensor	Verification Method	Acceptance
Wind	Compare with portable reference	± 0.5 m/s / $\pm 5^\circ$
Pressure	Compare with portable barometer	± 0.3 hPa
Temp/Humidity	Compare with portable reference	$\pm 0.2^\circ\text{C}$ / $\pm 2\%$
Ceilometer	Compare with known cloud heights (visual or reference)	± 50 ft up to 1,000 ft
Visibility/RVR	Compare with reference sensor or known RVR	$\pm 10\%$

Sensor	Verification Method	Acceptance
Present Weather	Visual observation of weather events	Correct identification
Lightning	Simulate or verify with network data	Alarm activation at set thresholds

- Ongoing calibration schedule and procedures provided for warranty period.

3.3 INTEGRATION WITH CNS SYSTEMS

- The AWOS should have its own workstations and display screens, and shall also output meteorological data to ATC display systems (tower display, approach radar) in agreed format.
- AWOS generates METAR, SPECI, trend reports in ICAO format and transmits to AMHS terminal via TCP/IP.
- Ambient audio (if recorded) time-synchronized with AWOS data; AWOS may generate voice-synthesized weather broadcasts for recording.
- AWOS CDU supports SNMPv3 for remote monitoring; alarms (sensor failure, communication loss, thresholds exceeded) forwarded to RCMS.

PART 4 – TESTING AND ACCEPTANCE

4.1 FACTORY ACCEPTANCE TEST (FAT)

Performed at manufacturer's facility for CDU and all sensors: sensor calibration verification, CDU data processing, report generation, communication interfaces. Witnessed by Employer and Engineer representatives (as per BOQ).

4.2 SITE ACCEPTANCE TEST (SAT)

Provisional SAT (PSAT): Verify all sensors installed per siting plan; cabling and grounding; power up; communication between sensors and CDU; data validity and report generation; alarms and interfaces.

Operational Readiness Demonstration (ORD): 60-day continuous operation; compare AWOS reports with manual observations or reference instruments; log alarms and events; Contractor corrects deficiencies.

Final SAT (FSAT): Repeat PSAT tests; verify calibration after ORD; demonstrate full functionality: METAR/SPECI generation, RVR calculation, alarm handling, remote monitoring, interface to ATC displays and AMHS.

PART 5 – DOCUMENTATION

Contractor shall provide as-built siting plan (coordinates, heights), cable routing and conduit diagrams, calibration certificates for all sensors, test reports (FAT, PSAT, FSAT), operation and maintenance manuals, spare parts list (recommended for 5 years), historical logbook for AWOS.

DIVISION 15 – AIRPORT SYSTEMS

SUB-DIVISION 15.1 – ATC CONSOLE FURNITURE

PART 1 – GENERAL

1.1 SCOPE

ATC console furniture for six working positions in the Skardu Airport control tower cab, providing ergonomic, durable, and functional workstations accommodating all CNS equipment including radio remote controllers, monitors, keyboards, fire alert panel, backup telephone, master clock, and ancillary equipment.

1.2 REFERENCES

FAA Order 6480.4, ISO 9241, EN 527, IEC 60950 (adapted).

1.3 SUBMITTALS

Detailed console drawings (plan, elevation, sections), material specifications and finishes, integration details for RRC, fire alert panel, backup telephone, master clock, cable management design, ergonomic assessment report.

PART 2 – PRODUCTS

2.1 CONSOLE FURNITURE (6 working positions)

2.1.1 General Configuration

- **Number of positions:** Six (6)
- **Layout:** Curved or linear arrangement per tower cab layout; positions grouped in two groups of three or continuous run
- **Dimensions per position:** Minimum 1.2 m width, 0.9 m depth (work surface)
- **Height:** Adjustable (electric or manual) 650-800 mm

2.1.2 Structure

- **Frame:** Heavy-duty steel, welded or bolted, powder-coated finish (RAL 7035 or as specified)
- **Work Surface:** High-pressure laminate (HPL) or solid surface, anti-static, scratch-resistant, rounded edges
- **Modesty Panel:** Steel or laminate, with cable access cutouts
- **Base:** Adjustable leveling feet or locking castors

2.1.3 Monitor Mounts

- Articulating arms (gas spring or mechanical), VESA 75/100 compatible; capacity three (3) monitors per position minimum; mounting at rear of work surface or integrated into console; adjustability in height, tilt, swivel, rotation.

2.1.4 Keyboard and Mouse Trays

- Pull-out tray with mouse platform (right or left); steel or aluminium, with wrist rest (optional); ball-bearing slides.

2.1.5 Equipment Integration

- RRC (6 units): Flush-mounted into console face with cut-outs to size; front access for operation.
- Fire alert panel, backup telephone, master clock: cut-out and mounting provisions.

2.1.6 Cable Management

- Integrated horizontal and vertical cable ducts (steel or plastic); front and rear access panels; separate channels for power (230 V AC) and data (Ethernet, audio); cable entry grommets at work surface; under-console trays.

2.1.7 Ergonomics and Finish

- Conforms to ISO 9241; adjustable for 5th to 95th percentile users.
- Anti-static (ESD-safe) work surface and components.
- Materials meet flame-retardant standards (UL 94 V-0 or equivalent).
- Color: RAL 7035 (light grey) or as per tower cab design.

2.1.8 Acceptable Manufacturers

Evans Consoles, Winsted, Hergo, Kustom, or equivalent meeting Clause 1.6.

PART 3 – EXECUTION

3.1 INSTALLATION

- Verify tower cab floor level and capable of supporting console weight; identify cable entry locations.
- Assemble consoles on-site by qualified technicians; join sections securely; level and align work surfaces.
- Flush-mount RRC controllers in designated cut-outs; attach monitors to articulating arms; install keyboard trays; install fire alert panel, backup telephone, master clock per coordination with other contractors.
- Route all cables through integrated ducts; separate power and data; use Velcro ties (no zip ties for service loops); provide service loops.

3.2 TESTING

- Verify all monitors and controllers securely mounted.
- Test adjustability of monitor arms and keyboard trays.
- Verify cable management allows maintenance access.

SUB-DIVISION 15.2 – ATC SUPPORT EQUIPMENT (MISCELLANEOUS)

PART 1 – GENERAL

1.1 SCOPE

Miscellaneous support equipment for ATC Tower: ergonomic chairs (10), storage lockers (4), binoculars (2), hand-held ATC signal light gun (1), and test equipment/tools for commissioning, maintenance, and troubleshooting of CNS systems.

1.2 REFERENCES

ISO 9241, EN 1335, EN 16122, IEC 60950 (adapted), ICAO Annex 10, FAA Order 6480.4.

1.3 SUBMITTALS

Product data (catalogue cuts, specifications, colors/finishes), shop drawings (locker placement), sample materials, test equipment list (manufacturer, model, specifications, intended use), operation and maintenance manuals.

PART 2 – PRODUCTS

2.1 ATC ERGONOMIC CHAIRS (Quantity: 10)

- Conforms to ISO 9241; adjustable seat height, seat depth, backrest angle, armrest height.
- Seat width ≥ 500 mm, depth adjustable 450-500 mm; upholstered with breathable, anti-static fabric; color approved.
- Backrest height adjustable 600-700 mm with lumbar support; tilt lock and free-float mechanism.
- Five-star base polished aluminium or heavy-duty nylon; rolling castors (≥ 50 mm) suitable for carpeted and hard floors.
- Synchronous mechanism linking seat and backrest; weight-adjustable tension control.
- Weight capacity minimum 150 kg.
- Tested to EN 1335; minimum 10-year warranty for mechanical components.
- Upholstery flame-retardant (BS 5852, CAL 117).
- Color approved by Engineer (dark grey, black, or blue).

Acceptable Manufacturers: Herman Miller (Aeron, Embody), Steelcase (Gesture, Leap), HÅG (Capisco), RH (Futu), or equivalent.

2.2 STORAGE LOCKERS (Quantity: 4)

- Welded steel frame, powder-coated paint (RAL 7035 or approved).
- Dimensions: width 2,000 mm (± 100 mm), height 2,100 mm (± 100 mm), depth 500 mm (± 25 mm).
- Minimum 7 adjustable heavy-gauge steel shelves; filing rails for suspended files (A4/legal) on at least two shelves.
- Horizontal folding doors (bi-fold or sliding) with lockable handles; individual or master key.
- Perforated or slotted ventilation.

- Anti-tip brackets and floor anchors included.
- Suitable for indoor use, corrosion-resistant finish.

Acceptable Manufacturers: Local reputable suppliers (subject to material specifications) or Spacesaver, Lista, etc.

2.3 BINOCULARS (Quantity: 2)

- Magnification 15× or higher; aperture 50 mm; field of view ≥60 m at 1,000 m.
- High-contrast, phase-coated, anti-reflective lenses.
- Central focus wheel with auto-focus or precision manual focus.
- Optical or electronic image stabilization.
- Roof prism (preferred) or Porro prism; eye relief ≥15 mm.
- Waterproof, fog-proof, nitrogen or argon sealed.
- Accessories: soft carry case, lens caps, neck strap, cleaning cloth, lens cleaning pen.
- Operating temperature –20°C to +50°C.

Acceptable Manufacturers: Zeiss, Leica, Swarovski, Fujinon, Canon (with IS), Nikon, or equivalent.

2.4 HAND-HELD ATC SIGNAL LIGHT GUN (Quantity: 1)

- Light colors: green, white, red (independently selectable).
- White light range ≥10 miles (16 km) in daylight, good visibility.
- Cordless, rechargeable internal Li-ion or NiMH battery; battery life ≥8 hours continuous operation.
- Mains-powered charger (110-240 V AC, 50/60 Hz) included; one spare battery pack included.
- Ergonomic pistol-grip design with trigger for each color; momentary or latching optional.
- Rugged, weather-resistant housing (IP54 minimum); weight <1.5 kg.
- Eye-safe at intended distances; comply with relevant safety standards.
- Accessories: carrying case, neck strap, cleaning cloth, instruction manual.

Acceptable Manufacturers: Honeywell (Whelen), Carmanah, Federal Signal, or equivalent ATC-certified suppliers.

2.5 TEST EQUIPMENT AND TOOLS (Minimum required)

Item	Quantity	Minimum Specification
Oscilloscope	1	100 MHz, 2-channel, digital storage, with probes
RF Power Meter / Wattmeter	1	2-500 MHz, power range 1 mW-100 W, directional, with adapters

Item	Quantity	Minimum Specification
Radio Communications Test Set	1	Covers VHF (118-137 MHz) and UHF (225-400 MHz); supports AM, FM, VoIP; signal generator, spectrum analyzer, modulation analyzer
Audio Frequency Generator	1	10 Hz-20 kHz, sine/square wave, adjustable output
Frequency Counter / Meter	1	10 Hz-3 GHz, accuracy ± 1 ppm
Digital Multimeters	2	True-RMS, CAT III 600 V, AC/DC voltage, current, resistance, capacitance, frequency
Analog Voltmeters	2	Portable, AC/DC ranges, high impedance
Clamp-on Ammeters	2	AC/DC, 0-200 A, with DC current capability
Cable Test Set (end-to-end)	1	For copper and RF cables; tests continuity, length, VSWR (optional)
Fiber Optic Tester	1	OTDR or light source/power meter for single-mode OS2; includes launch cable, adapters
VSWR / Return Loss Meter	1	Field-portable (e.g., Anritsu Site Master) covering VHF/UHF; with calibration kit
Ethernet Cable Qualifier	1	For Cat6a shielded cabling; tests wiremap, length, insertion loss, NEXT, etc.
Spectrum Analyzer	1	Portable, 9 kHz-3 GHz, with tracking generator (optional)
Tool Sets (electronics)	2 sets	Precision screwdrivers, pliers, cutters, soldering station, desoldering tools, anti-static mat, wrist strap
Tool Sets (electrical/mechanical)	2 sets	Combination wrenches, socket set, hex keys, wire strippers, crimping tools (coaxial and data), torque wrench

All test equipment supplied with manufacturer's calibration certificates traceable to national/international standards; include carrying cases, adapters, cables, consumables.

Acceptable Manufacturers: Anritsu, Rohde & Schwarz, Keysight, Fluke, Tektronix, Bird, Aeroflex (Viavi), or equivalent.

PART 3 – EXECUTION

3.1 INSTALLATION

- Chairs delivered fully assembled; placed at designated ATC working positions.

- Lockers installed in approved locations; secured to floor or wall with anti-tip brackets; level and aligned.
- Binoculars stored in control cab at secure location; mounting brackets (if required) per manufacturer.
- Light gun provided with charging station installed in control cab or designated area; charging station connected to AC outlet and grounded; spare battery stored same location.
- Test equipment delivered in appropriate carrying cases; stored in designated cabinets or lockers; Contractor shall inventory all items and provide list with serial numbers.

3.2 ACCEPTANCE AND DEMONSTRATION

- Chairs: verify adjustability, ergonomic comfort, no defects.
- Lockers: verify dimensions, shelving, locking mechanism, finish.
- Binoculars: demonstrate image quality, stability; verify accessories.
- Light gun: demonstrate all three colors; verify daylight visibility (simulated); test battery charging and spare battery operation.
- Test equipment: demonstrate basic functions of each instrument; present calibration certificates.

3.3 WARRANTY AND SPARE PARTS

- Chairs: manufacturer's warranty ≥ 5 years for mechanical parts.
- Light gun: 2 years warranty on electronics and battery.
- Test equipment: 1-year warranty (or per manufacturer) with calibration validity at delivery. Contractor to provide list of recommended spare parts for test equipment (leads, fuses, connectors) for 2 years.

DIVISION 16 – SPECIAL SECTIONS (Testing, Training, Documentation)

SUBDIVISION 16.1 – QUALITY CONTROL (TESTING AND ACCEPTANCE)

PART 1 – GENERAL

1.1 SCOPE

Testing and acceptance requirements for all CNS equipment, AWOS, and associated systems, including Factory Acceptance Tests (FAT), Site Acceptance Tests (SAT), Operational Readiness Demonstration (ORD), and flight checks (if applicable).

1.2 SUBMITTALS

Document	Submission Timing
FAT Plan and Procedures	30 days prior to FAT
SAT Plan and Procedures	30 days prior to PSAT
Test Records	Within 10 days after each test phase
Acceptance Certificates	Upon successful completion

PART 2 – PRODUCTS

(Not applicable)

PART 3 – EXECUTION

3.1 FACTORY ACCEPTANCE TEST (FAT)

3.1.1 General

- FAT performed at OEM manufacturing facility for each major system: VHF/UHF/HF Radios, DVLS, RCMS, AWOS.
- Employer and Engineer representatives (as per BOQ Table No. 2) witness.
- Contractor provides all test equipment, power, consumables.

3.1.2 FAT Plan and Procedures

Includes test schedule, step-by-step procedures with pass/fail criteria, test equipment list (with calibration certificates), configuration details.

3.1.3 FAT Content

System	Tests to be Performed
VHF/UHF Radios	Power output, sensitivity, modulation, VoIP (ED-137C) latency, SNMPv3, main/standby redundancy, BITE alarms

System	Tests to be Performed
DVLS	Channel recording, timestamp accuracy, synchronized replay, RAID redundancy, failover, NTP sync
RCMS	Device discovery, SNMP trap generation, remote configuration, report generation, user access control
AWOS	Sensor calibration verification, CDU data processing, METAR generation, RVR calculation, alarm handling
Integration	End-to-end scenarios (radio transmission, recording, RCMS alarm)

3.1.4 FAT Completion

- All test results recorded and signed.
- Deficiencies corrected prior to shipment.
- FAT Certificate issued upon successful completion.

3.2 SITE ACCEPTANCE TEST (SAT)

3.2.1 General

SAT conducted in three phases:

- PSAT (Provisional SAT): installation verification, basic functionality
- ORD (Operational Readiness Demonstration): 60 days continuous operation under normal conditions
- FSAT (Final SAT): repeat critical tests, full system demonstration

3.2.2 PSAT (Provisional SAT)

- **Installation Verification:** visual inspection (mounting, labelling, cabling), grounding continuity tests, power supply verification, network connectivity.
- **Functional Tests:** VHF/UHF/HF power output, receiver sensitivity, VoIP streams; remote controllers PTT, audio quality, LAN redundancy; DVLS channel recording/replay; RCMS device status/alarms; AWOS sensor data acquisition/report generation; UPS/DC power transfer to battery, runtime verification.

3.2.3 ORD (Operational Readiness Demonstration)

- 60-day continuous operation.
- System operated by Employer personnel (with Contractor support).
- All failures, alarms, anomalies logged.
- Contractor corrects all deficiencies within specified response times.
- Acceptance: no unresolved critical deficiencies after 60 days.

3.2.4 FSAT (Final SAT)

- Repeat all PSAT functional tests.
- Demonstrate full system integration: radio → RCMS → DVLS (recorded audio); AWOS → ATC display → AMHS.
- Verify all ORD deficiencies corrected.
- Submit final test records.
- FSAT Certificate issued upon successful completion.

3.3 FLIGHT CHECK (IF APPLICABLE)

- If navigation aids (ILS, DME, DVOR, NDB) included, Contractor coordinates flight inspection with civil aviation authority at no additional cost to Employer. Any deficiencies corrected by Contractor.

DEMONSTRATION AND TRAINING

PART 1 – GENERAL

1.1 SCOPE

Factory and on-site training for Employer personnel to operate, maintain, and troubleshoot supplied systems.

1.2 SUBMITTALS

Document	Submission Timing
Training Curriculum	60 days prior to training
Training Schedule	30 days prior to training
Training Materials	At start of training
Training Completion Reports	After each training session

PART 2 – PRODUCTS

(Not applicable)

PART 3 – EXECUTION

3.1 FACTORY TRAINING

- Conducted at OEM manufacturing facility per BOQ Table No. 1.
- Instruction in English.
- Contractor provides travel, accommodation, DSA as per BOQ.

Training Content:

System	Topics
VHF/UHF/HF Radios	System architecture, installation, configuration, Level 1/2 maintenance, troubleshooting, VoIP/SNMP setup
DVLS	Recording configuration, replay operations, system administration, backup/restore, maintenance
RCMS	Server/client configuration, SNMP management, alarm handling, report generation
AWOS	Sensor calibration, CDU operation, report generation, troubleshooting
General	Preventive maintenance schedules, use of test equipment, fault isolation to module level

- Format: Classroom (theory) 50%, hands-on practical 50%. Each trainee receives training manuals and course materials.
- Evaluation and completion certificates provided.

3.2 SITE TRAINING

- Conducted at Skardu Airport after installation.
- Covers both operations and maintenance personnel.

Operations Training: Normal system operation, emergency procedures, alarm recognition and response, use of remote controllers, DVLS replay client, RCMS monitoring.

Maintenance Training: Daily/weekly/monthly preventive maintenance, troubleshooting procedures, module replacement, software updates, use of diagnostic tools.

- Format: On-the-job training with actual equipment; demonstration and supervised practice.

DIVISION 17 – CLOSEOUT SUBMITTALS (DOCUMENTATION)

PART 1 – GENERAL

1.1 SCOPE

Final documentation to be delivered by Contractor upon project completion.

1.2 SUBMITTALS

All documentation submitted before Final Acceptance.

PART 2 – PRODUCTS

(Not applicable)

PART 3 – EXECUTION

3.1 AS-BUILT DRAWINGS

Three (3) hard copies and one (1) digital copy (PDF and editable CAD format) of:

- System block diagrams (as-built)
- Equipment layout drawings (cabinets, racks, consoles)
- Cable routing diagrams (RF, data, power)
- Grounding and lightning protection drawings
- Antenna mast installation drawings
- AWOS sensor siting plan
- Conduit and cable tray routing

3.2 OPERATION AND MAINTENANCE MANUALS

Three (3) hard copies and one (1) digital copy of:

- **Functional Design Manual:** System overview, block diagrams, operational scenarios, interface control documents
- **Hardware Manuals:** Installation instructions, schematics, parts lists, alignment procedures
- **Software Manuals:** Installation, configuration, backup/recovery, software version control
- **Operator Manuals:** Step-by-step operation, alarm handling, normal and emergency procedures
- **Maintenance Manuals:** Preventive maintenance schedules, fault finding flowcharts, module replacement

All manuals in English, bound in hardback loose-leaf binders with tabbed sections.

3.3 HISTORICAL LOGBOOKS

- One (1) hardbound logbook per site (equipment room, ATC tower, AWOS).
- Used to record installation, commissioning, maintenance, failures, modifications.

- Contractor records initial entries (installation dates, test results, configuration details).

3.4 CERTIFICATE OF COMPLIANCE

Certificate signed by Contractor and OEM confirming all equipment conforms to specifications, covering any modifications made during installation.

3.5 TEST RECORDS

- FAT reports for all systems
- PSAT, ORD, and FSAT reports
- Ground resistance test reports
- VSWR and RF test reports
- AWOS calibration certificates

3.6 SPARE PARTS LIST

- Recommended spare parts for 5 years of operation
- Manufacturer part numbers, descriptions, quantities, recommended storage conditions

SECTION 0750 — AIRPORT OPERATIONAL SAFETY REQUIREMENTS

PART 1 — GENERAL

1.1 SCOPE

This Section sets out the airport-specific safety, security and coordination requirements applicable to all Works carried out within, or in the vicinity of, the operational area of Skardu International Airport. These requirements are additional to, and not in substitution of, the general Health, Safety and Environment requirements of Section 0010. Where any conflict arises between this Section and any other Section of Volume-II, the requirements of this Section shall govern in matters of aerodrome operational safety.

1.2 DEFINITIONS

Aerodrome Operator means the Pakistan Airports Authority through the Aerodrome Manager, Skardu International Airport. CAA means the Civil Aviation Authority of Pakistan. ASF means the Airport Security Force. NOTAM means a Notice to Airmen issued by the Air Traffic Services unit. OLS means the Obstacle Limitation Surfaces as defined in ICAO Annex 14 Volume I Chapter 4. OFZ means the Obstacle-Free Zone. FOD means Foreign Object Debris.

PART 2 — REQUIREMENTS

2.1 NOTAM AND CRANE OPERATIONS

The Contractor shall not erect or operate any crane, hoist, scaffold, mast or other equipment that penetrates the Obstacle Limitation Surface of the active runway without prior written approval of the Aerodrome Operator and the issue of a NOTAM by the Air Traffic Services unit. Crane sweep diagrams, height above runway elevation, proposed operating hours and the corresponding NOTAM text shall be submitted to the Engineer and to the Aerodrome Operator not less than fourteen (14) calendar days before the planned operation. All operations shall be conducted under continuous two-way radio contact with ATC on a frequency designated by the Aerodrome Operator. The Contractor shall install red obstruction lights on the top of any crane operating overnight inside the aerodrome perimeter, at his own cost.

2.2 AIRSIDE ACCESS AND SECURITY

All personnel and vehicles entering the airside shall hold a valid Airport Security Pass issued by the ASF and the Aerodrome Operator. All Contractor vehicles operating airside shall be escorted by an Aerodrome Operator representative. The Contractor shall nominate a Security Officer who shall be responsible for the daily roster of passes, the surrender of passes on completion of the work, and the immediate reporting of lost or stolen passes. The pass register shall be available for inspection by the Engineer, ASF and the Aerodrome Operator at all times.

2.3 FOREIGN OBJECT DEBRIS (FOD) CONTROL

The Contractor shall maintain FOD discipline at all times. All tools, fasteners, nuts, bolts and small components carried airside shall be accounted for at the start and at the end of each shift. A daily FOD walk shall be conducted on all airside roads and apron areas under the Contractor's control. Loose granular materials, off-cuts, packaging and waste shall be removed from airside the same day they are generated. Wheel washes shall be installed at every boundary between the construction area and any airside surface. Any FOD incident shall be reported immediately to the Aerodrome Operator.

2.4 FRANGIBILITY

All items installed within the Object-Free Zone of any runway or taxiway shall be frangible in accordance with ICAO Annex 14 Volume I Chapter 9 and ICAO Doc 9157 Part 6, and shall break, distort, yield or otherwise give way upon impact by an aircraft without imposing dangerous loads. This requirement applies, in particular, to signage, light pole bases, antenna masts, fences, conduits and any temporary works within the OFZ. Drawings for items located within the OFZ shall carry the legend “FRANGIBLE — ICAO Doc 9157 Part 6”.

2.5 COORDINATION WITH NAVIGATION AIDS AND RADIO FACILITIES

Where the Works are within 300 m of any operational ILS, VOR, NDB, DME, or VHF air-ground antenna of the Aerodrome Operator, the Contractor shall obtain a separate Method Statement approval from the Aerodrome Operator before bringing metallic plant or scaffolding into the area. The Aerodrome Operator shall monitor RF interference, signal reflection and ground-plane disturbance during the activity and may require flight inspection of any disturbed aid; flight-inspection cost arising from the Contractor’s activity shall be borne by the Contractor.

2.6 WILDLIFE AND BIRD MANAGEMENT

The Contractor shall not create any condition attractive to birds or wildlife on the site, including standing water, food waste, exposed waste bins or fruit-bearing plantation. Closed waste skips shall be used and removed daily. The Contractor shall report any bird strike on Contractor vehicles, or any observed concentration of birds attributable to construction activity, immediately to the Aerodrome Operator’s Wildlife Hazard Management focal point.

2.7 HOT WORK NEAR FUEL

No hot work (welding, cutting, grinding, brazing) shall be performed within 25 m of any fuel installation, fuel hydrant pit, fuel-storage tank, or active fueling vehicle without a written Hot Work Permit issued by the Aerodrome Operator and the attendance of a stand-by ARFF appliance at the Contractor’s cost. The 25 m exclusion shall be increased to 50 m for grinding operations producing spark showers.

2.8 DUST, BLAST AND VIBRATION CONTROL

Construction activity shall not cause dust plumes that intrude into the visual cone of the existing or the new ATC cabin, nor onto the active runway or taxiways. Blasting is prohibited within the aerodrome perimeter without specific written approval and, where approved, shall be conducted under a separate Method Statement coordinated with the Aerodrome Operator. Peak particle velocity at any operational navigation aid foundation shall not exceed 25 mm/s; the Contractor shall monitor and record this.

2.9 EMERGENCY COORDINATION

The Contractor shall participate in the Aerodrome Emergency Plan exercises convened by the Aerodrome Operator during the construction period, and shall provide a 24-hour emergency contact who is authorised to halt construction works on instruction from the Aerodrome Operator or from the Air Traffic Services unit.

SECTION 0760 — FIRE STOPPING OF PENETRATIONS

PART 1 — GENERAL

1.1 SCOPE

This Section covers the supply and installation of fire-stop systems for all penetrations of fire-rated walls, floors and ceilings by services (pipes, conduits, cable trays, ducts), and the firestopping of joints,

voids and gaps in the fire-rated construction. The fire-resistance rating of each penetration seal shall equal or exceed the rating of the construction it penetrates.

1.2 STANDARDS

All fire-stop systems shall be third-party certified to one of the following: ASTM E814 / UL 1479; BS EN 1366-3 and BS EN 1366-4; ISO 10295-1. Acceptable performance categories are F-rating equal to the construction rating, and T-rating where life-safety occupancy lies on the unexposed side. Smoke leakage (L-rating) shall meet UL 1479 Annex C ≤ 5 cfm/ft² at 0.30 in. WC.

1.3 SUBMITTALS

- System type-test certificates and design listings for every penetration condition on the project.
- Manufacturer's installation instructions and method statement.
- Schedule of all penetrations cross-referenced to construction drawings.
- Sample installation for Engineer's inspection in each typical condition before bulk installation.

PART 2 — PRODUCTS

2.1 FIRE-STOP MATERIALS

- Intumescent sealant for cable and small-pipe penetrations.
- Mortar (gypsum-cement) for large openings and floor penetrations.
- Mineral-wool batts with elastomeric coating on both faces for cable-tray and duct penetrations.
- Intumescent pipe collars or wraps for plastic pipes (PVC, uPVC, PE) per BS EN 1366-3.
- Fire-rated dampers (UL 555 / EN 1366-2) in HVAC ducts crossing rated walls or floors, with thermal-release link and electric position monitor wired to the BMS.

2.2 ACCEPTABLE MANUFACTURERS

Hilti (Firestop systems), 3M (Fire Barrier), Promat (Promaseal), Rockwool / Rockflam, Nullifire, or equivalent meeting Section 0010 §1.06.

PART 3 — EXECUTION

3.1 INSTALLATION

Fire stops shall be installed by personnel trained and certified by the system manufacturer. Each installed seal shall be tagged with an identification label showing the date, the installer's name, the rating and the certified system reference. Records of every installed penetration, with photographs before and after installation, shall be kept by the Contractor and submitted with the As-Built drawings.

3.2 INSPECTION

The Engineer or the manufacturer's representative shall inspect a random 10% of all penetrations before close-out of the rated barrier (false ceiling, ductwork enclosure, etc.). Any non-conforming installation shall be removed and reinstalled at the Contractor's cost, and the inspection sample doubled for the area concerned.

SECTION 0770 — AIRCRAFT WARNING AND OBSTRUCTION LIGHTING

PART 1 — GENERAL

1.1 SCOPE

This Section covers the supply, installation, testing and commissioning of the aircraft warning and obstruction lighting on the New Air Traffic Control Tower and on any other structure or appurtenance designated as an obstacle by the Aerodrome Operator under ICAO Annex 14 Volume I Chapter 6 and CAA-Pakistan CAR Part 139.

1.2 STANDARDS

ICAO Annex 14 Volume I, Chapter 6, latest amendment; ICAO Aerodrome Design Manual Doc 9157 Part 4; FAA AC 150/5345-43 (LED obstruction lights, where applicable); CAA-Pakistan CAR Part 139, Aerodrome Standards. Where conflicts arise, ICAO Annex 14 and CAR Part 139 shall govern.

1.3 SUBMITTALS

- Photometric data for proposed luminaires demonstrating compliance with ICAO Annex 14 Table 6.3.
- Coordination drawings showing the lights placed against the OLS analysis.
- Failure-mode and alarm-interface drawings to the BMS and to the RCMS.

PART 2 — PRODUCTS

2.1 TOP-MOST OBSTRUCTION LIGHT

Medium-Intensity Type A obstruction light at the top of the tower mast: LED, white flashing 20–60 fpm, peak intensity 20,000 cd day / 2,000 cd twilight / 2,000 cd night, photocell or BMS day/night switching, dual-lamp head with automatic switch-over on lamp failure, IP66, operating range –40 °C to +55 °C, individual lamp failure monitoring with dry contact for BMS.

2.2 INTERMEDIATE OBSTRUCTION LIGHTS

Low-Intensity Type B fixed-red obstruction lights at intermediate levels (where the tower height exceeds 45 m above ground), LED, peak intensity 32 cd, dual-lamp head, IP66, operating range –40 °C to +55 °C, mounted at the levels notified by the Aerodrome Operator after the OLS analysis. Number of lights and their levels shall be confirmed before installation.

2.3 MASTER CONTROL UNIT

Master control unit located in the Equipment Control Room (ECR) with day/night automatic switching via photocell with manual override; alarm contacts (lamp failure, panel failure, supply failure) wired to the BMS and to the Remote Control and Monitoring System (RCMS) of Section 0740; dual feed from the emergency board and from the UPS to ensure no-break operation.

PART 3 — EXECUTION

3.1 INSTALLATION

Luminaires shall be installed on hot-dip galvanised steel brackets, with vibration isolators where mounted on antenna masts. Cable to the top-most luminaire shall be a single continuous run from the ECR with no joints; cable type LSZH, fire-rated to BS 6387 Cat. C/W/Z.

3.2 TESTING AND COMMISSIONING

Night-time inspection from at least three approach bearings shall be performed by the Engineer and the Aerodrome Operator. A failure-mode test by removal of one lamp shall verify the automatic switch-over and the alarm at the ECR and the BMS. The system shall be left running continuously for 30 days as part of the Reliability Trial.

SECTION 0780 — VOICE ALARM AND PUBLIC ADDRESS SYSTEM

PART 1 — GENERAL

1.1 SCOPE

A combined Voice Alarm (VA) and Public Address (PA) system serving the ATC Tower, the Fire Station, and allied facilities, with full integration to the Fire Alarm Control Panel (Section 0660) and to the BMS (Section 0710 §1.5). The system shall transmit pre-recorded evacuation messages, live announcements from a fire-brigade microphone, and routine paging announcements, with priority override of routine traffic by emergency messages.

1.2 STANDARDS

EN 54-16 (Voice Alarm Control and Indicating Equipment); EN 54-24 (Voice Alarm Loudspeakers); NFPA 72 Chapter 24 (Emergency Communication Systems); IEC 60268-16 (Speech Transmission Index); EN 50849 (Sound Systems for Emergency Purposes). All active components shall be third-party certified to EN 54.

PART 2 — PRODUCTS

2.1 CENTRAL RACK

19-inch rack with redundant amplifiers (N+1) Class-D, digital message store (minimum 16 messages of up to 90 seconds each), routine paging microphone with zone selection, fire-brigade microphone with priority override (red, hinged-cover, lockable), end-of-line monitoring of every loudspeaker circuit per EN 54-16, A and B paths with line-fault diagnosis, integral 24 V DC back-up battery for 30 minutes of full-alarm load after 24 hours quiescent supervision.

2.2 LOUDSPEAKERS

Ceiling and wall-mounted loudspeakers as appropriate, all EN 54-24 certified, 100 V line, with ceramic thermal fuses providing line-integrity preservation under fire conditions. Loudspeakers in ARFF apparatus bays shall be IP65 horn type with a sound power level adequate to override running vehicle noise.

2.3 ZONING

Minimum zoning: ATCT ground / mezzanine / first floor; ATC cab; ECR/OCR; ARFF apparatus bay; ARFF ancillary areas; OCC; multipurpose hall; external announcement (apron and access road). Each zone individually addressable from the routine microphone and overridable by the fire-brigade microphone.

PART 3 — EXECUTION

3.1 INSTALLATION AND COMMISSIONING

Sound pressure level at 1.0 m above floor: minimum 65 dB(A) in occupied office spaces, minimum 75 dB(A) in plant rooms and vehicle bays, with a Speech Transmission Index (STI) of not less than 0.50 measured per IEC 60268-16. Commissioning shall include audibility and STI measurement at one sample point per 50 m² of occupied area; results documented and signed off by the Engineer.

SECTION 0790 — ACCESS CONTROL SYSTEM

PART 1 — GENERAL

1.1 SCOPE

An electronic Access Control System for the ATC Tower, the Fire Station and the Utility Building, providing access regulation, audit trail, anti-passback, and integration with the Fire Alarm and BMS systems. The system shall cover all external doors, all rooms designated security-controlled on the architectural drawings (ATC cab, ECR, OCC, OCR, server room, ARFF bays, archive, fuel store), and the gates of the airside compound.

1.2 STANDARDS

EN 60839-11-1 (Electronic Access Control Systems); UL 294 (Access Control System Units); ISO/IEC 14443 (Contactless Identification Cards); ASF and CAA-Pakistan requirements for airport access control.

PART 2 — PRODUCTS

2.1 READERS

Multi-class proximity readers (ISO/IEC 14443A/B + MIFARE Plus or DESFire EV2), with optional biometric (fingerprint or palm-vein) for highest-security doors (ATC cab, ECR, server room, fuel store). All readers IP65 for external use, operating range -20 °C to +60 °C, vandal-resistant polycarbonate housing, integral LED and beeper, anti-tamper switch.

2.2 CONTROLLERS

Distributed IP controllers, each supporting up to 8 doors with local decision-making and 50,000-event offline buffer; communication to head-end over the structured cabling network (Section 0650), with encrypted protocol; battery back-up of 4 hours minimum.

2.3 ELECTRIC LOCKS

Fail-safe electric strikes or electromagnetic locks on all egress doors (so that loss of power releases the door). Fail-secure locks permitted only on secure storerooms with manual key override. All electromagnetic locks rated 600 lbf minimum, with bond sensor and door-position sensor.

2.4 HEAD-END SOFTWARE

Server-based management software with role-based administration, audit trail with 365-day retention, anti-passback, time-zone scheduling, photo-ID badging, and integration interface to the FACP (automatic release of all locks on FACP general alarm, with override on fire-brigade input only), to the CCTV (camera call-up on alarm), and to the BMS for status display.

SECTION 0800 — MATV / IPTV SYSTEM

PART 1 — GENERAL

1.1 SCOPE

A combined Master Antenna Television (MATV) and IPTV system for the distribution of free-to-air and licensed television channels, plus internal channels (ATC operational displays, CCTV viewing, airport public-information channel), to TV outlet points in the dormitories, common areas, cafeteria, OCC, ARFF rest areas and ATC briefing areas indicated on the electrical drawings.

PART 2 — PRODUCTS

2.1 HEAD-END

Satellite head-end with prime-focus dish (1.2 m minimum), LNB, multi-input receiver, IRD, IP/RF transcoder for IPTV streaming over the structured cabling network. Free-to-air channels and licensed channels as agreed with PAA. Head-end rack mounted in the ECR with conditioned power from the UPS board.

2.2 DISTRIBUTION

Co-axial RG-11 trunk, RG-6 drops; or, where IPTV is adopted exclusively, distribution over Cat 6A to set-top boxes at each TV outlet. Outlets located on the architectural drawings (Drawings E-01 through E-67 as applicable). Output level at TV outlet: 60 ± 5 dB μ V for analogue, $BER \leq 1 \times 10^{-9}$ for IPTV.

SECTION 0810 — MASTER CLOCK SYSTEM

PART 1 — GENERAL

1.1 SCOPE

A precision master-clock system distributing a common, traceable time reference to all systems on the project that require a synchronised time-stamp: the Air Traffic Control consoles, the CNS voice recorders (DVLS), the Remote Control and Monitoring System (RCMS), the CCTV, the Fire Alarm Control Panel, the Access Control System, and the BMS.

1.2 STANDARDS

ICAO Annex 11 (UTC for ATC); IEEE 1588 (Precision Time Protocol); RFC 5905 (NTP v4); ITU-T G.811 / G.812 (clock accuracy). Time reference UTC.

PART 2 — PRODUCTS

2.1 MASTER CLOCK

GPS-disciplined master clock with internal Rubidium or OCXO holdover oscillator providing accuracy better than 1×10^{-12} over 24 hours of GPS loss; outputs: NTP server (dual Ethernet ports), PTP master (IEEE 1588v2), IRIG-B (coded analogue), and dry contact 1 pulse per second. GPS antenna roof-mounted with lightning arrestor and surge suppressor. Dual master-clock units in hot-standby (Master + Backup) with automatic failover.

2.2 SLAVE CLOCKS

Digital slave clocks in all operational rooms (ATC cab, ECR, OCR, OCC, ARFF watch-room, ARFF apparatus bay, multipurpose hall) and analogue slave clocks in administrative offices, all synchronised over NTP/PoE. Display: 6-digit (hh:mm:ss) for operational rooms, 4-digit (hh:mm) for administrative.

PART 3 — EXECUTION

3.1 DISTRIBUTION

All time-stamping systems on the project shall be configured to take their time reference from the master clock NTP server. The Contractor shall produce a Time Distribution Schedule listing every device, its IP address and its NTP polling interval. Time-stamp consistency between FACP, DVLS, CCTV, Access Control and BMS shall be verified during commissioning by injecting a simulated event into the FACP and checking that the timestamps recorded on the other systems are within ± 100 ms of each other.

SECTION 0820 — AUTOMATIC FIRE DETECTION SYSTEM (AFDS)

PART 1 — GENERAL

1.1 SCOPE

An Aerodrome Fire Detection System providing automatic detection of fire along both runway ends, as required by the Terms of Reference. The system shall annunciate at the ATC cab, the ARFF watch-room and the BMS, and shall be integrated with the building Fire Alarm Control Panel (Section 0660).

1.2 STANDARDS

ICAO Doc 9137 Part 1 (Rescue and Fire Fighting); NFPA 415 (Aircraft Fuel Servicing and ARFF Building); EN 54-22 (Linear Heat Detectors); EN 54-26 (Carbon Monoxide Detectors); UL/FM listed video flame and smoke detection.

PART 2 — PRODUCTS

2.1 DETECTION TECHNOLOGIES

The AFDS shall employ a combination of the following, as agreed in the technical bid evaluation: (a) Linear Heat Detection cable (analogue addressable) along the runway shoulder cable trench; (b) UV/IR video flame detectors at the runway end safety areas (RESA), with cone of vision covering the threshold and the first 300 m of runway; (c) Aspirated smoke detection in the ARFF apparatus bay and in any aviation fuel storage area within the project; (d) Hydrocarbon vapour detection at any fuel handling area. All field devices shall operate over the temperature range -40°C to $+75^{\circ}\text{C}$ and shall be sealed to IP67.

2.2 CONTROL PANEL

Dedicated AFDS control panel in the ARFF watch-room with mimic display of the airfield layout, annunciation of every detection zone, dry contacts to the building FACP for cross-alarm, and a network interface to the ATC cab for visual and audible alert. Power supply from emergency board with battery back-up to maintain operation for at least 24 hours of mains failure.

PART 3 — EXECUTION

3.1 FIELD INSTALLATION

Linear heat detection cable installed in HDPE conduit in the cable trench along the runway shoulder, at depth and offset agreed with the Aerodrome Operator. Junction boxes flush with grade and frangible per Section 00750 §2.4. Video flame detectors on frangible masts of height not exceeding 3 m, located outside the OFZ.

3.2 TESTING

Functional test by controlled application of a calibrated heat source to the linear cable and a calibrated flame source within the video field of view. All annunciation paths (AFDS panel → FACP → ATC cab → ARFF watch-room) shall be verified. Tests shall be repeated by the Aerodrome Operator during the Reliability Trial.

SECTION 0830 — ARFF VEHICLE EXHAUST VENTILATION

PART 1 — GENERAL

1.1 SCOPE

Dedicated vehicle-exhaust ventilation for the ARFF apparatus bay, designed and installed entirely independent of the comfort HVAC and smoke-control systems, in accordance with the HVAC Basis of Design. The system shall capture diesel exhaust gases at the tail-pipe of stationary or starting vehicles, and shall provide general dilution ventilation during routine operations.

1.2 STANDARDS

ACGIH "Industrial Ventilation" Manual; NFPA 88B / NFPA 30A (where applicable); ASHRAE 62.1 for dilution component; OSHA 1910.146; AMCA 99/210/300 for fans.

PART 2 — PRODUCTS

2.1 SOURCE CAPTURE

Tail-pipe capture system with reel-mounted high-temperature flexible hose (rated 250 °C continuous, 600 °C peak), tail-pipe adaptor sized for the ARFF vehicle exhaust diameter, automatic disconnect with vehicle motion, manual reel for retraction. One source-capture point per vehicle bay, mounted on the bay structure clear of the door opening sweep.

2.2 DILUTION VENTILATION

General dilution ventilation rate not less than 6 air changes per hour (ACH) under normal operation, increasing to 12 ACH on demand from CO/NO₂ sensors, by a step-controlled or VFD-controlled exhaust fan installation. The fan installation shall be N+1 with one duty and one standby fan; both fans wired to the emergency board.

2.3 MONITORING

Carbon monoxide sensors (alarm at 25 ppm 8-hour TWA), nitrogen dioxide sensors (alarm at 3 ppm), and combustible gas sensors (alarm at 10% LEL diesel vapour), all wired to a dedicated annunciator in the ARFF watch-room and to the BMS.

2.4 DISCHARGE

Exhaust discharge location coordinated with the Aerodrome Operator: located clear of the ATC cabin visual cone (no plume across the controllers' line of sight) and separated by not less than 10 m from any fresh-air intake per ASHRAE 62.1.

SECTION 0840 — SMOKE MANAGEMENT

PART 1 — GENERAL

1.1 SCOPE

Smoke-management systems comprising (a) staircase pressurisation of the tower stair core, (b) smoke exhaust of the multipurpose hall and any atrium / double-height space identified on the architectural drawings, and (c) automatic shut-down of comfort HVAC and DOAS on Fire Alarm general signal.

1.2 STANDARDS

NFPA 92 (Standard for Smoke Control Systems); NFPA 92A (Smoke Control Systems for Stair-tower Pressurisation); BS EN 12101-6 (Pressure Differential Systems); ASHRAE Smoke Control Design Guide.

PART 2 — PRODUCTS

2.1 STAIR PRESSURISATION

Dedicated fan supplying air to the tower stair core to maintain a positive pressure of 50 Pa (± 12.5 Pa) relative to adjacent spaces with the stair door open at the discharge floor and a 0.83 m² vent open on the fire floor. Fan shall be located at the top of the stair shaft, duty/standby configuration not required by code but a single fan of robust class is acceptable; VFD modulating the fan speed against pressure sensors at three levels. Supply from emergency generator board.

2.2 SMOKE EXHAUST

Where the multipurpose hall or any other space exceeds the area or height thresholds of NFPA 92, a smoke-exhaust system shall be provided with a calculated exhaust rate to maintain the smoke layer 1.8 m above the highest occupied floor. Make-up air through automatic dampers or doors. Fan: 250 °C / 2-hour rated; supply from emergency generator board.

2.3 HVAC SHUT-DOWN ON FIRE

All AHUs, FCUs and DOAS shall be hard-wired to shut down automatically on general fire-alarm signal from the FACP. Fire-rated dampers shall close automatically at every penetration of a fire-rated barrier.

PART 3 — EXECUTION

3.1 COMMISSIONING

Stair pressurisation: door-open and door-closed tests at every floor with pressure-difference measurement at three points; fan-failure test verifying alarm. Smoke exhaust: hot-smoke test (or full-scale smoke test) witnessed by the Engineer and by the Aerodrome Operator. All HVAC shut-down interlocks tested by injection of a simulated fire signal at the FACP.

SECTION 0850 — GLYCOL FREEZE-PROTECTION PACKAGE

PART 1 — GENERAL

1.1 SCOPE

Freeze protection of the chilled-water and condenser-water hydronic loops at Skardu International Airport, where the winter design temperature is -18°C and the equipment qualification envelope reaches -25°C . Without active freeze protection these loops will rupture during the first winter shut-down. The Section covers the glycol fluid, the automatic make-up unit, the immersion heaters in the hydronic loops, the self-regulating heat-tracing on exposed pipework, the expansion provision for glycol volumetric change, and the BMS interface.

1.2 STANDARDS

ASHRAE Handbook — Refrigeration, Chapter 31 (Secondary Coolants); ASTM D1384 (glycol-based corrosion test); ISO 21055 (heat-tracing equipment); IEEE 515.1 (heating cables for industrial applications).

PART 2 — PRODUCTS

2.1 GLYCOL FLUID

USP-grade propylene glycol (not ethylene glycol) mixed with treated water to give a freeze point of -20°C and a burst point below -40°C , with a corrosion-inhibitor package compatible with copper, brass, mild steel and stainless steel. Glycol concentration 35–40% by volume.

2.2 MAKE-UP UNIT

Factory-packaged automatic glycol make-up unit comprising: 200-litre minimum storage tank, stainless-steel pump, suction strainer, pressure switch, level switches (low / high / low-low), discharge pressure gauge, integral controller with dry-contact alarm output, and manual fill connection. Make-up to the loop on falling system pressure.

2.3 IMMERSION HEATERS

Electric immersion heaters with Incoloy 800 sheath, mounted in dedicated wells on both the chilled-water and the condenser-water headers in the Utility Building. Heater rating sized to maintain the loop above $+2^{\circ}\text{C}$ with the chillers off and no fluid movement at the design winter ambient. Thermostatic control at $+5^{\circ}\text{C}$, with a separate high-limit cut-out at $+15^{\circ}\text{C}$ and a low-temperature alarm at 0°C wired to the BMS.

2.4 PIPE HEAT-TRACING

Self-regulating heat-tracing cable rated 10 W/m at 10°C , applied to the underside of the pipe insulation on all hydronic, water-supply, drainage and condensate pipework exposed to ambient temperatures below $+4^{\circ}\text{C}$. Cable temperature controlled by ambient or pipe thermostat set at $+5^{\circ}\text{C}$ with a high-limit at $+35^{\circ}\text{C}$, supplied from the emergency generator board through a dedicated panel.

2.5 EXPANSION AND VENTING

Closed expansion tank, bladder type, sized for the additional volumetric expansion of the glycol mix over the full operating temperature range. Air separator and automatic air vent at every high point of the system.

2.6 BMS INTERFACE

Alarms reporting to the BMS: glycol concentration low (refractometer or alternative), loop low-temperature at any sensor, immersion-heater failure, heat-trace circuit continuity loss, make-up running for excessive time (leak indication).

PART 3 — EXECUTION

3.1 COMMISSIONING

The glycol mix shall be tested by refractometer before and after charging; results shall be recorded for each circuit. Heat-trace continuity shall be tested before insulation is applied. Immersion heaters shall be functionally tested by simulating loop low-temperature. The expansion tank pre-charge shall be verified before commissioning.

3.2 DEFECT-LIABILITY MAINTENANCE

The Contractor shall check glycol concentration and inhibitor reserve at six-monthly intervals during the Defect Liability Period and shall top-up or replace the fluid as required, at his own cost. Records shall be furnished to the Engineer.

SECTION 0860 — PRECISION COOLING FOR ATC EQUIPMENT AND DATA-CENTRE SPACES

PART 1 — GENERAL

1.1 SCOPE

Dedicated precision cooling (CRAC / CRAH) of the ATC Equipment Room, the Communication Operations Room (OCR), the Data-Centre / IDF Rooms and any other mission-critical, continuously-occupied equipment space identified on the architectural and HVAC drawings. The systems shall operate independently of the building occupancy schedule, 24 hours per day, every day, and shall be supported by emergency power and UPS for controls and alarms.

1.2 STANDARDS

ASHRAE TC 9.9 "Thermal Guidelines for Data Processing Environments"; AHRI 1361 (Computer Room Air Conditioners); EN 14511 (Performance ratings); EN 60204-1 (electrical safety).

PART 2 — PRODUCTS

2.1 UNIT TYPE

Chilled-water-cooled CRAH units, with internal DX backup coil where indicated on drawings, 20 kW to 80 kW per unit per the cooling load calculation. Units configured for in-row, perimeter or under-floor delivery as shown on the drawings; hot-aisle / cold-aisle containment in the Data Centre. Set-point: 22 $\pm$ 1 $^{\circ}$ C, 45–55 % RH.

2.2 REDUNDANCY

N+1 per cooling sub-system. The failure of any one unit shall not result in a temperature excursion outside the ASHRAE TC 9.9 "Allowable" envelope for the equipment class concerned.

2.3 MONITORING

Each unit shall be fitted with: condensate pump (with high-level alarm); under-floor or in-cabinet leak-detection cable; supply, return and rack-inlet temperature sensors; humidity sensors; airflow proving switch; filter dirty switch; refrigerant leak detector (where DX backup fitted). All alarms wired to the BMS and to the RCMS of Section 0740.

2.4 POWER

Each precision cooling unit shall be supplied from a dedicated MCB on the emergency-generator board. Control transformers and alarm circuits shall be on UPS supply to ensure that alarm and monitoring continue through the generator transfer.

PART 3 — EXECUTION

3.1 COMMISSIONING

Functional test of each unit, redundancy test by simulated failure of the lead unit (the standby unit shall take over within 30 seconds without the rack-inlet temperature rising above 27 $^{\circ}$ C), alarm path test for every monitored point. Twenty-four-hour soak test under simulated heat load (load bank) verifying temperature and humidity stability.

SECTION 0870 — SOLAR PHOTOVOLTAIC (PV) SYSTEM

PART 1 — GENERAL

1.1 SCOPE OF WORK

This Section covers the complete design, supply, installation, testing, commissioning, and integration of a Grid-Tied Solar Photovoltaic (PV) System with Battery Energy Storage System (BESS) for the Air Traffic Control Tower (ATCT), Fire Station, and Allied Facilities at Skardu International Airport. The system shall supplement utility (WAPDA) power and provide reliable backup power for critical loads including ATCT operational equipment, emergency lighting, and fire station functions. The BOQ requirement is 250 kWp with 10-hour backup (BOQ Item 14.01).

The work shall include, but shall not be limited to, the following:

- Solar PV array: monocrystalline silicon modules on purpose-built galvanized steel mounting structures
- Hybrid grid-tied inverters with MPPT and anti-islanding protection
- Battery Energy Storage System (BESS) — Lithium Iron Phosphate (LiFePO4) technology
- DC and AC distribution boards, wiring, and protection devices
- Surge protection devices (SPDs) for DC and AC sides
- Earthing and lightning protection dedicated to the PV system
- Remote monitoring and supervisory control system with data logging
- Integration with the Building Management System (BMS) per Section 0880 of this document
- As-built drawings, O&M manuals, and operator training

1.2 REFERENCE STANDARDS

Standard / Code	Scope of Application
IEC 61215	Crystalline Silicon Terrestrial PV Modules — Design Qualification and Type Approval
IEC 61730	PV Module Safety Qualification
IEC 62109-1/2	Safety of Power Converters for Use in PV Power Systems
IEC 60364-7-712	Electrical Installations — Solar Photovoltaic Systems
IEC 62548	PV Array Design Requirements
IEC 62116	Test Procedure for Grid-Connected Inverter Anti-Islanding Protection
IEC 62619	Safety Requirements for Secondary Lithium Cells and Batteries (BESS)
IEC 61643-11/31	Surge Protective Devices — AC and DC sides
BS 7671	IET Wiring Regulations — Requirements for Electrical Installations
IEEE 1547	Standard for Interconnection of Distributed Energy Resources
ICAO Annex 14	Aerodrome Design and Operations — Electrical Supply Provisions
NEPRA Net Metering Rules 2015	WAPDA Grid Connection and Net Metering Regulations (with amendments)
Pakistan Electricity Rules 1937	As adopted and modified by Government of Pakistan

Standard / Code	Scope of Application
BCP	Building Code of Pakistan

1.3 CLIMATIC AND SITE CONDITIONS

All PV system equipment shall be designed and rated to operate reliably under the following Skardu site conditions without developing any defect or reduction in performance:

Parameter	Design Value
Maximum Ambient Temperature	41°C (105°F)
Minimum Ambient Temperature	-20°C (-04°F)
Maximum Relative Humidity	90% — Non-condensing
Altitude above MSL	Approximately 2,228 m (7,310 ft) — altitude de-rating to be confirmed
Seismic Zone	Zone 4 (High Seismicity) — BCP-SP-07 compliance mandatory for mounting structures
Design Wind Speed (Gust)	150 km/h — IBC / ASCE 7 or BCP-SP-07 for structural mounting design
Snow Load	Minimum 1.5 kN/m ² — panels tilted $\geq 10^\circ$ to allow snow shedding
Peak Sun Hours (PSH)	Minimum 5.5 PSH/day (annual average) — PVsyst simulation required
Solar Irradiance (GHI)	Minimum 5.0 kWh/m ² /day (design basis)

1.4 SYSTEM PERFORMANCE REQUIREMENTS

The Solar PV system shall be designed to meet the following minimum performance requirements. The BOQ mandates 250 kWp installed capacity with 10-hour battery backup; the contractor shall confirm sizing through a formal load analysis and energy yield simulation (PVsyst or equivalent):

Parameter	Minimum Requirement
Installed PV Capacity	250 kWp minimum (BOQ Item 14.01) — exact number of modules per detailed design
System Configuration	Hybrid grid-tied with Battery Energy Storage — synchronised with WAPDA and generator
Battery Backup Duration	Minimum 10 hours for critical loads (BOQ requirement); at 50% DoD
System Efficiency (Overall)	$\geq 83\%$ — PV module DC output to AC bus
Performance Ratio (PR)	≥ 0.78 at Standard Test Conditions (STC)
Voltage THD at AC Output	$\leq 3\%$ at rated output
Current THD at AC Output	$\leq 5\%$ at rated output
Anti-Islanding Response Time	≤ 2 seconds per IEC 62116

Parameter	Minimum Requirement
Design Life — PV Modules	Minimum 25 years
Design Life — BESS	Minimum 10 years / 4,000 cycles
Monitoring Data Granularity	15-minute interval data logging; 5-minute resolution for alarm events

1.5 SUBMITTALS

The Contractor shall submit the following for the Engineer's written approval prior to commencing procurement or installation. All submittals in triplicate hard copy and electronic format:

- System design report: load analysis, PV array sizing, shading analysis, energy yield simulation (PVsyst), BESS sizing for 10-hour backup
- Complete equipment data sheets and manufacturer's technical brochures for all major items
- Structural design calculations for PV mounting systems — signed and stamped by a registered structural engineer
- Electrical design drawings: single-line diagram, array layout, conduit routing, earthing scheme
- Shop drawings for all installations; load balancing chart for solar AC distribution board
- Factory test certificates for PV modules, inverters, and BESS
- Proposed commissioning and testing procedures
- Operation and Maintenance (O&M) manuals in English and Urdu
- Operator training program outline

1.6 QUALITY ASSURANCE

Installer Qualifications: The PV system installation shall be performed by a firm with a minimum of five (5) years' experience in commercial or industrial PV system installation. The installation team shall include at least one engineer holding a recognised PV system design certification (PVTEC, TÜV, or equivalent).

Manufacturer Qualifications: All major equipment manufacturers shall hold ISO 9001 certification. PV module manufacturers shall additionally hold IEC 61215 and IEC 61730 type-test certifications.

1.7 GUARANTEE AND WARRANTY

Item	Warranty Requirement
PV Module — Power Output Warranty	≥ 90% of rated power at Year 10; ≥ 80% of rated power at Year 25
PV Module — Product Warranty	Minimum 12 years against manufacturing defects
Inverter Warranty	Minimum 5 years; extendable to 10 years preferred
Battery Energy Storage System (BESS)	Minimum 10 years or 4,000 full cycles at 80% capacity retention — whichever is first
Mounting Structure — Structural Integrity	25 years against structural failure
Mounting Structure — Galvanising	10 years hot-dip galvanising integrity
Overall System Workmanship	12 months from issue of Completion Certificate per Contract Conditions

PART 2 — PRODUCTS

2.1 PV MODULES

PV modules shall be monocrystalline PERC (Passivated Emitter and Rear Cell) or HJT (Heterojunction) type, new and unused, meeting the following minimum specifications at STC (1,000 W/m², AM 1.5, 25°C):

Parameter	Specification
Cell Technology	Monocrystalline PERC or HJT (Heterojunction) — bifacial permitted if yields better performance
Nominal Peak Power (P _{max})	≥ 450 Wp per module at STC; tolerance 0/+5%
Module Efficiency	≥ 20.5% at STC
Open Circuit Voltage (V _{oc})	≥ 49 V
Short Circuit Current (I _{sc})	≥ 11.5 A
Maximum Power Point Voltage (V _{mp})	≥ 41 V
Maximum Power Point Current (I _{mp})	≥ 11.0 A
Temperature Coefficient — P _{max}	≤ -0.35% / °C
Temperature Coefficient — V _{oc}	≤ -0.28% / °C
NOCT (Nominal Operating Cell Temp.)	≤ 45°C ± 2°C
Junction Box IP Rating	IP68
Mechanical Load Resistance	≥ 5,400 Pa front load / 2,400 Pa rear load per IEC 62773
Frame Material	Anodised aluminium alloy; ≥ 40 mm frame height
Front Glass	High-transmission tempered solar glass ≥ 3.2 mm; anti-reflective coating
Back-Sheet / Rear	Fluoropolymer composite or glass (for bifacial)
Connector Type	MC4 or compatible IP67-rated
Certification	IEC 61215, IEC 61730, MCS or equivalent, ISO 9001
Acceptable Manufacturers	Jinko Solar, LONGi, Trina Solar, Canadian Solar, or approved equivalent

2.2 PV MOUNTING STRUCTURES

Mounting structures shall be designed specifically for the roof/ground conditions at Skardu Airport and shall accommodate the seismic zone, wind, and snow loading requirements of Clause 1.3. Structural design calculations signed by a registered structural engineer are mandatory before fabrication.

Parameter	Specification
Material	Hot-dip galvanised structural steel (minimum 85 µm zinc coating) or Aluminium alloy 6005A-T5

Parameter	Specification
Tilt Angle	Fixed — optimised for Skardu latitude (~35°N); exact angle per PVsyst simulation
Azimuth	South-facing ($180^\circ \pm 5^\circ$)
Inter-Row Spacing	Calculated to avoid shading at winter solstice (sun elevation angle $< 20^\circ$)
Foundation Type	Reinforced concrete footings for ground mount; ballasted or anchor-bolted for flat roofs — per structural design
Wind Load Design	150 km/h design gust — IBC / ASCE 7 or BCP-SP-07
Snow Load Design	1.5 kN/m ² minimum; panels tilted $\geq 10^\circ$ for self-clearing
Seismic Design	Zone 4 per BCP-SP-07; base shear and connection forces per structural calculations
Corrosion Protection	All fasteners and hardware: stainless steel 304/316 SS; dissimilar metal contacts isolated with neoprene or PTFE pads
Cable Management	Integrated cable clips, conduit channels, and pull-out access points in mounting rails
Aesthetic	Uniform finished appearance; no exposed raw cut edges; all cable runs concealed
Structural Warranty	25 years against structural failure; 10 years hot-dip galvanising

2.3 GRID-TIED / HYBRID INVERTERS

Inverters shall be string type or central type as determined by the system design, and shall support both grid-connected and battery-storage (hybrid) operation:

Parameter	Specification
Inverter Type	Three-phase grid-tied / hybrid string inverter with independent MPPT trackers
AC Output Voltage	415 V, 3-Phase, 4-Wire, 50 Hz ($\pm 2\%$)
MPPT Voltage Range	200 V – 800 V DC (minimum operating window)
Maximum DC Input Voltage	1,000 V DC (IEC standard) or 1,500 V DC as per detailed design
Maximum DC Input Current per MPPT	Per detailed string design — typically ≥ 12.5 A
European Weighted Efficiency (η_{EU})	$\geq 97\%$
CEC / California Weighted Efficiency	$\geq 97\%$
Power Factor Range	Adjustable 0.8 leading to 0.8 lagging; unity at full rated load
Isolation Method	Transformer-isolated or transformerless with ground fault monitoring — as per design

Parameter	Specification
Protection Features	Anti-islanding (IEC 62116), over/under voltage, over/under frequency, DC overvoltage, DC reverse polarity, short circuit, earth fault, PV insulation monitoring
Display / HMI	Colour LCD with real-time energy production, battery SoC, grid status
Communication Interfaces	RS485 Modbus RTU; Ethernet Modbus TCP/IP; CAN Bus (for BESS); optional Wi-Fi
Enclosure Rating	IP65 minimum — rated for outdoor installation
Operating Temperature Range	-25°C to +50°C
Altitude De-rating	Rated performance up to 2,000 m; de-rating calculation submitted for Skardu (2,228 m)
Standards / Certification	IEC 62109-1/2, IEC 62116, CE, VDE-AR-N 4105
Acceptable Manufacturers	SMA, Fronius, ABB/FIMER, Huawei, Sungrow, or approved equivalent
Inverter Warranty	Minimum 5 years from Completion Certificate; extendable to 10 years (preferred)

2.4 BATTERY ENERGY STORAGE SYSTEM (BESS)

The BESS shall provide a minimum 10 hours of backup at rated critical load (BOQ Item 14.01). Chemistry shall be Lithium Iron Phosphate (LiFePO₄) for inherent thermal stability and safety:

Parameter	Specification
Battery Chemistry	Lithium Iron Phosphate (LiFePO ₄) — inherently thermally stable; non-toxic; non-flammable electrolyte
Total Usable Energy Capacity	Sized per detailed load analysis for 10-hour critical load backup — minimum 200 kWh usable at project BOQ scale; exact capacity per design
Depth of Discharge (DoD)	Maximum 80% for daily cycling; minimum SoC maintained at 20% for cell protection
Round-Trip Efficiency (RTE)	≥ 95% at standard conditions
Cycle Life	≥ 4,000 full discharge cycles at 80% depth while retaining ≥ 80% rated capacity
Battery Management System (BMS)	Integrated; cell-level voltage, temperature, and SoC monitoring; automatic cell balancing; overcharge, over-discharge, over-temperature, short-circuit protection
Communications	CAN Bus (internal); RS485 Modbus RTU; optional Ethernet (Modbus TCP/IP) to BMS/inverter
Operating Temperature — Charging	-15°C to +45°C

Parameter	Specification
Operating Temperature — Discharging	-20°C to +55°C
Storage Temperature	-20°C to +50°C
Enclosure Rating	IP55 minimum; metal cabinet construction
Fire Safety Compliance	Thermal management with active cooling; integrated smoke and temperature sensors; NFPA 855 compliant installation room
Installation Requirements	Dedicated, well-ventilated room; minimum 0.9 m maintenance clearance; NFPA 855 safety signage
Certification	IEC 62619 (safety), UN 38.3 (transport testing), UL 9540A (fire safety)
Acceptable Manufacturers	CATL, BYD, Pylontech, Sungrow (SBR series), or approved equivalent
BESS Warranty	Minimum 10 years or 4,000 cycles at 80% capacity retention — whichever first

2.5 DC DISTRIBUTION AND PROTECTION

Component	Specification
DC String Combiner Boxes	IP65 rated; individual string-level fusing (per IEC 60269-6); string monitoring (current and voltage); MC4-compatible cable entries; surge protection included
DC Surge Protection Devices (SPDs)	Type 2 SPDs on positive and negative conductors per IEC 61643-31; Class II transient voltage protection; replaceable modules
DC Disconnect Switches	Lockable load-break isolating switches; rated for DC operating voltage of the array; one per inverter/array segment
DC Circuit Breakers	IEC 60947-3 rated for DC service; appropriate voltage class; UV-stabilised enclosure where roof-mounted
DC Cable	UV-resistant, halogen-free, single-core PV cable; TÜV 2 Pfg 1169 certified; minimum 4 mm ² or as designed; rated at 1,500 V DC
Cable Routing	Positive and negative conductors in same conduit run — minimum 25 mm UV-resistant PVC conduit; separate from AC conduit system
Connectors	MC4 or compatible IP67-rated field-installable connectors; no un-insulated connections permitted anywhere in DC system

2.6 AC DISTRIBUTION AND PROTECTION

Component	Specification
AC Main Disconnect / MCCB	MCCB rated per detailed design; 415 V, 3-phase; integrated with Main LT Switchboard per Electrical Design Report Section 9
AC Distribution Board (Solar DB)	As per Electrical Design Report Section 11; separate dedicated solar AC DB

Component	Specification
AC Cables	PVC/XLPE insulated copper conductor per Electrical Design Report Section 3 and BOQ (25 mm ² as specified in Item 14.01)
AC Surge Protection Devices (SPDs)	Type 1+2 combined SPD at main DB per IEC 61643-11; Class I + II combined protection
Earth Leakage Protection	RCCB/ELCB as per Electrical Design Report Section 11; sensitivity as designed
Grid Synchronisation	Auto-synchronisation with WAPDA supply; load sharing panel per BOQ Item 14.01

2.7 MONITORING AND SUPERVISORY CONTROL SYSTEM

A comprehensive monitoring, data acquisition, and remote supervisory control system shall be provided as an integral part of the PV system:

- Central data logger with local colour display; minimum 1-year on-board data storage at 15-minute resolution
- Revenue-grade energy meters on AC output: Class 0.5 per IEC 62053; Modbus RTU communication
- String-level DC current and voltage monitoring via combiner boxes — all strings individually monitored
- Ambient temperature sensor and pyranometer (Class A preferred per ISO 9060) for irradiance measurement
- Module temperature sensors: minimum one Pt100 sensor per PV array string group
- BESS data integration: state of charge (SoC), cell voltages, temperatures, cycle count, alarms — via CAN/Modbus
- Web-based remote monitoring portal with email and SMS alarm notifications; access via secure HTTPS
- Modbus TCP/IP communication protocol for BMS integration per Section 0880 of this document
- Real-time dashboard and historical data: daily/monthly/annual energy production, self-consumption, export/import
- Performance ratio (PR) and specific yield reporting; automated monthly energy report generation

PART 3 — EXECUTION

3.1 INSTALLATION

All installation shall comply with the requirements of Section 1 (General) of the Electrical Design Report — including prequalification, rules and regulations, climatic conditions, and submittal requirements — which are incorporated herein by reference. The following additional requirements apply:

Site Assessment and Preparation

- Prior to installation, the Contractor shall conduct a site survey and verify roof/ground structural load capacity for PV mounting. Written sign-off from a registered structural engineer is required before any mounting work commences.
- Shading analysis shall be performed using a solar path analyser at the proposed installation location to confirm no significant shading during the peak generation months.

PV Module Handling and Installation

- Modules shall be handled strictly per manufacturer guidelines at all times. Walking on, standing on, or placing heavy objects on modules is strictly prohibited.
- Temporary protective covers shall protect installed modules from construction dust and debris until final commissioning.
- All module frames shall be bonded to the mounting structure earthing system using stainless steel earthing clips and copper wire per IEC 60364-7-712.

Conduit and Cable Management

- DC wiring shall be installed in separate conduit from AC wiring throughout the entire system — no shared conduit runs between DC and AC circuits.
- Minimum conduit size for PV DC wiring: 25 mm UV-resistant PVC conduit for all exposed outdoor runs.
- All outdoor conduit entry points into junction boxes and combiner boxes shall be sealed with waterproof compound to prevent moisture ingress.
- Cable dressing in mounting rails shall be neat, supported at maximum 400 mm intervals, and free from abrasion points.

BESS Installation

- BESS cabinets shall be installed in a dedicated, well-ventilated room with forced exhaust ventilation; room shall have appropriate fire detection and suppression.
- Minimum 0.9 m clearance shall be maintained on all service-access sides of BESS cabinets.
- BESS room signage per NFPA 855: 'ENERGY STORAGE SYSTEM — LITHIUM ION BATTERIES' and emergency contact information.
- BESS cabinets shall be seismically restrained per Zone 4 BCP-SP-07 requirements.

Earthing and Bonding

- Complete equipotential bonding of all metallic components — module frames, mounting structures, inverter enclosures, BESS cabinets — per IEC 60364-7-712, BS 7430, and Electrical Design Report Section 16.
- A separate dedicated earth electrode shall be provided for the PV system unless combined earthing is specifically approved in writing by the Engineer.

Labeling

- All DC cables, AC cables, combiner boxes, inverters, disconnects, and BESS cabinets shall be permanently labeled with durable, UV-resistant engraved or embossed nameplates.
- DC positive and negative conductors shall have colour coding or permanent ferrule labels throughout their length.
- Warning labels: 'DUAL SOURCE — DISCONNECT BOTH INVERTER AND GRID BEFORE WORKING' at all relevant points.

3.2 TESTING AND COMMISSIONING

Prior to energisation, the Contractor shall perform and document the following tests in the presence of the Engineer:

Test	Acceptance Criterion / Method
Insulation Resistance — DC Cables	Minimum 500 V DC Megger; IR $\geq$ 10 M Ω on each string before connection to inverter
Insulation Resistance — AC Cables	500 V AC Megger; IR $\geq$ 5 M Ω per Electrical Design Report Section 17

Test	Acceptance Criterion / Method
Array Voc Verification	Measured open-circuit voltage per string compared against calculated value at measured cell temperature; accept within $\pm 2\%$
Array Isc Verification	Short-circuit current per string compared against calculated value; accept within $\pm 5\%$
Earth Continuity	All bonded metallic components: $\leq 1 \Omega$ per Electrical Design Report Section 17
Anti-Islanding Function Test	Disconnect grid supply and verify all inverters shut down within 2 seconds per IEC 62116
BESS Charge/Discharge Cycle Test	Verify correct operation at 20%, 50%, and 80% DoD; verify BMS alarms function at set points
Grid Synchronisation Test	Verify auto-synchronisation with WAPDA supply; confirm load sharing panel operation
Monitoring System Validation	Verify all data points (string, inverter, BESS, weather) displayed correctly; trigger alarms and verify notifications
Power Quality Measurement	Measure voltage THD, current THD, power factor, and frequency at AC output during normal operation
Performance Ratio (PR) Measurement	7-day continuous baseline monitoring period; $PR \geq 0.78$ required before final acceptance

3.3 TRAINING

The Contractor shall provide a minimum of two (2) days of comprehensive operator training for the Employer's designated personnel, covering: system operation and monitoring, routine preventive maintenance, fault diagnosis and alarm response, inverter reset procedures, safety procedures (DC arc flash, electrical isolation), monitoring system usage, and emergency shutdown procedures. Training materials shall be provided in both English and Urdu.

3.4 MEASUREMENT AND PAYMENT

The complete solar PV system shall be measured and paid as a lump sum per BOQ Item 14.01, which includes PV modules (250 kWp), mounting structures, hybrid inverter, BESS (10-hour backup), Electrical Synchronising and Load Sharing Panel, 25 mm² AC cables, DC cables, combiner boxes, SPDs, earthing, monitoring system, and commissioning. Civil works for foundations and BESS room are included unless separately itemised in the BOQ.

SECTION 0880 — BUILDING MANAGEMENT SYSTEM (BMS)

PART 1 — GENERAL

1.1 SCOPE OF WORK

This Section covers the complete design, supply, installation, testing, commissioning, and training for a fully integrated Building Management System (BMS), also referred to as Building Automation System (BAS), for the Air Traffic Control Tower (ATCT), Fire Station, and Allied Facilities at Skardu International Airport. The BMS shall provide centralised monitoring, control, alarm management, and data logging for all major building services systems. Refer to BOQ Item 12.01.

The BMS shall integrate the following building services as a minimum:

- HVAC systems — air handling units (AHUs), fan coil units (FCUs), split AC units, ventilation systems, chilled water/DX plant
- Electrical power systems — main LT switchboard, sub-main distribution boards (monitoring only, no control)
- Solar PV and Battery Energy Storage System (BESS) — integration with Section 0870 of this document via Modbus TCP/IP
- Diesel generator sets — status, run hours, fuel level, electrical load, alarms
- Uninterruptible Power Supply (UPS) — status, battery health, input/output voltage, alarms
- Fire detection and alarm system — read-only status integration only (per NFPA/EN 54 system requirements)
- Lighting control system — scheduled switching, daylight harvesting, occupancy-based control
- Water supply and sanitary systems — pump status, tank levels, water meters
- Access control and security system — door status monitoring, alarm zones (read-only integration)
- Energy metering — kWh, kVAR, power factor monitoring per major feeder

1.2 REFERENCE STANDARDS

Standard / Protocol	Application
ASHRAE Guideline 13	Specifying Direct Digital Control (DDC) Systems
ASHRAE 135 (BACnet)	Data Communication Protocol for Building Automation and Control Networks — primary protocol
ISO 16484-2	Building Automation and Control Systems (BACS) — Part 2: Hardware
ISO 16484-5	BACS — Part 5: Data Communication Protocol (BACnet)
IEC 62443	Industrial Communication Networks — Network and System Security (Cybersecurity)
IEC 60364	Electrical Installations of Buildings — wiring of BMS control panels
EN 50090	Home and Building Electronic Systems (HBES)
LONworks / KNX	Open field bus protocols — accepted as alternative to BACnet MS/TP for field devices
Modbus RTU / TCP	Serial and Ethernet data communication — for sub-system integration (meters, UPS, Solar, Generator)

Standard / Protocol	Application
OPC Unified Architecture (OPC-UA)	Process data exchange for higher-level integration
BS 7671	IET Wiring Regulations — Low Voltage Installations — BMS panel wiring

1.3 SYSTEM ARCHITECTURE REQUIREMENTS

The BMS shall be a distributed, open-protocol system based on BACnet/IP (ASHRAE 135) as the primary communication protocol. Proprietary closed systems requiring exclusive service agreements or proprietary-only hardware are NOT acceptable. The architecture shall comprise three tiers:

Tier	Description
Tier 1 — Field Level	Field sensors, actuators, meters, and Local Controllers (DDC/PLCs) communicating via BACnet MS/TP, Modbus RTU, LONworks, or KNX over field buses
Tier 2 — Automation Level	Floor-level or system-level Advanced Application Controllers (AACs) and Application Specific Controllers (ASCs) communicating via BACnet/IP over Ethernet LAN
Tier 3 — Management Level	Central BMS Operator Workstation (OWS) with supervisory control, graphical user interface (GUI), historian database, alarm management, energy reporting, and remote access via secure VPN

1.4 PREQUALIFICATION AND QUALIFICATIONS

The BMS Contractor or Sub-Contractor shall be a recognised system integrator formally authorised by the BMS manufacturer. The following shall be submitted with the tender bid: evidence of manufacturer authorisation, a minimum of five (5) completed BMS projects of comparable scale in commercial or institutional buildings, and the BMS project engineer's BACnet International certification or equivalent recognised credential.

1.5 SUBMITTALS

The Contractor shall submit the following for the Engineer's written approval before commencing any work:

- BMS design report: system architecture, complete points list (minimum 300 I/O points), control strategies narrative, integration interfaces with Solar PV, generators, UPS, fire alarm, and access control
- Complete equipment data sheets: controllers, I/O expansion modules, operator workstation hardware and software
- BACnet/IP network diagram and IP addressing scheme — including VLAN design
- Graphic screen layouts for each major system (minimum draft before installation; final before commissioning)
- Control Sequence of Operations (CSO) document for each HVAC system and controlled sub-system
- Wiring diagrams and control panel layout drawings (submitted before fabrication)
- Factory Acceptance Test (FAT) procedure — to be reviewed and approved by Engineer
- Site Acceptance Test (SAT) procedure and test record forms

- Cybersecurity plan per IEC 62443: network segmentation, access control, patch management

1.6 GUARANTEE AND WARRANTY

Item	Warranty Requirement
BMS Software and Licenses	Minimum 5 years software maintenance and license support; no time-expiring licenses for basic operational functionality
BMS Hardware — Controllers and I/O Modules	Minimum 2 years manufacturer warranty on all hardware components
Operator Workstation Hardware	Minimum 2 years manufacturer warranty
Workmanship	12 months from issue of Completion Certificate per Contract Conditions
Spare Parts Availability	Manufacturer shall guarantee availability of all spare parts for minimum 10 years from date of system installation

PART 2 — PRODUCTS

2.1 BMS CONTROLLERS

2.1.1 Advanced Application Controller (AAC)

AACs shall provide supervisory and coordination functions for each major building system or floor zone:

Parameter	Specification
Processor	32-bit RISC processor; dedicated embedded BMS controller — not a general-purpose PC
Communication Ports	Minimum: 2× Ethernet RJ45 (BACnet/IP), 1× RS485 (BACnet MS/TP or Modbus RTU), 1× USB (local programming / firmware update)
Onboard I/O	As required per detailed design; all I/O fully expandable via I/O expansion modules
Flash Memory	Non-volatile flash ≥ 8 MB for program storage; retains programming on power loss
RAM	≥ 256 MB for runtime operation and data buffering
Real-Time Clock	Hardware RTC with integrated battery backup; NTP synchronisable over Ethernet
Communication Protocols	BACnet/IP (primary mandatory); Modbus TCP/RTU, LONworks, KNX as integration gateways
Enclosure	DIN-rail mounted; NEMA 1 (IP30 minimum) lockable powder-coated steel panel
Power Supply	24 V AC/DC; all critical controllers backed by UPS for minimum 2 hours autonomy
Operating Temperature	0°C to +50°C

Parameter	Specification
Certifications	BACnet Testing Laboratories (BTL) listed — mandatory; CE; UL 916 or equivalent

2.1.2 Application Specific Controller (ASC)

ASCs (e.g., VAV box controllers, FCU controllers, fan coil unit controllers) shall be BTL listed, factory pre-configured, BACnet MS/TP protocol, and physically and electrically interchangeable with other controllers of the same type from the same manufacturer. Manufacturer interoperability declaration (PICS) required.

2.2 INPUT / OUTPUT MODULES

I/O Type	Specification
Analog Inputs (AI)	Input types selectable via software: 0–10 V DC, 4–20 mA, thermistor (10 k Ω NTC/PTC), RTD (Pt100/Pt1000)
Analog Outputs (AO)	0–10 V DC, 4–20 mA; 10-bit minimum resolution; short-circuit protected
Digital Inputs (DI)	Volt-free dry contact (status/alarm); opto-isolated; pulsed input for energy meter pulse output
Digital Outputs (DO)	Relay SPDT output $\geq$ 5 A at 230 V AC; or solid-state triac output for lighting/fan control
I/O Isolation	Minimum 1,500 V isolation between field circuits and internal logic circuits
Module Protection	Surge protection on all I/O field terminals; short-circuit protection on all output modules
Hot-Swap Capability	I/O modules shall be hot-swappable without power-down of the controller

2.3 OPERATOR WORKSTATION (OWS)

Parameter	Specification
Computer Hardware	Industrial-grade PC or workstation; Intel Core i7 (10th Generation or later); 16 GB DDR4 RAM; 512 GB NVMe SSD; Windows 10/11 Pro (64-bit)
Monitor	Minimum 27" colour LED monitor; 1920 × 1080 resolution; dedicated solely for BMS operation
BMS Software	Fully licensed SCADA/HMI software suite; open-licence models permitted; 5-year annual maintenance and support included
Graphic Screens	Minimum one screen per major system; ATCT floor-by-floor electrical and HVAC overview; airport site plan overview with colour-coded zone status
Alarm Management	Prioritised alarm list with four severity levels (Critical, High, Medium, Low); time-stamped alarm log; email and SMS notification with configurable escalation
Trending and Data Logging	All analog BMS points trended at 15-minute intervals minimum; 2-year on-site compressed archive storage; export to CSV/Excel

Parameter	Specification
Reporting	Automated daily, weekly, and monthly energy consumption and fault reports; export in PDF and Excel formats
Remote Access	Secure VPN-based remote access for Employer's designated staff and factory technical support; role-based access
Cybersecurity	Role-based access control (RBAC); encrypted communications (TLS 1.2 minimum); network segmentation per IEC 62443; audit trail logging
Database Backup	Automatic daily database backup to internal redundant storage; cloud backup optional

2.4 NETWORKING EQUIPMENT

Component	Specification
BMS LAN	Dedicated VLAN logically separated from IT/corporate network on campus switch infrastructure — OR independent Cat6 STP cabling to BMS devices
Network Switches	Industrial-grade managed Ethernet switches; DIN-rail mountable; operating range -40°C to +70°C; PoE+ where required for field devices
Cabling	CAT6 STP (Shielded Twisted Pair) for BMS LAN; minimum performance Category 6 per TIA-568; armoured cable in EMI-prone areas (near transformers, VFDs)
IP Router / Firewall	Dedicated stateful-inspection firewall between BMS network and corporate/IT network; default-deny rule set; IEC 62443-compliant configuration
BMS Conduit	Dedicated separate conduit system from all power wiring; minimum 20 mm PVC conduit per Electrical Design Report Section 2; minimum 150 mm separation from LV power cables

2.5 FIELD INSTRUMENTATION AND SENSORS

All field instruments and sensors shall be compatible with the BMS controller I/O specifications and shall comply with applicable IEC or BS standards. The following types are required as a minimum:

Sensor Type	Specification
Temperature Sensors — Water Systems	Immersion type; Pt1000 RTD; stainless steel pocket; 4–20 mA or 0–10 V output; IP65; range -10°C to +120°C
Temperature Sensors — Air / Duct	Duct-mount or space type; Pt100 or 10 k Ω NTC; 4–20 mA output; IP54; range -30°C to +80°C
Temperature Sensors — Outdoor	Wall-mount; IP65; 4–20 mA; sun shield provided
Humidity Sensors	Capacitive type; $\pm 2\%$ RH accuracy; 0–100% RH range; 4–20 mA or 0–10 V output; duct or wall-mount
Pressure / DP Transmitters	Piezoresistive type; 4–20 mA; IP65; range and span per system requirements; for water, air, and refrigerant circuits

Sensor Type	Specification
Flow Meters — Water	Electromagnetic type (no moving parts); pulse or 4–20 mA output; accuracy $\pm 0.5\%$; flanged connections per pipe size
Energy Meters	kWh / kVAR / PF / current / voltage; Class 0.5 per IEC 61557-12; Modbus RTU RS485; DIN-rail; 3-phase 4-wire; MID-approved
CO ₂ / Air Quality Sensors	NDIR (Non-Dispersive Infrared) type; 0–2,000 ppm range; ± 50 ppm accuracy; wall-mount; for all occupied spaces in ATCT and offices
Occupancy Sensors	PIR (Passive Infrared) type; ceiling-mount; 360° coverage; integrated with lighting control and HVAC setback mode

2.6 HVAC CONTROL VALVES AND ACTUATORS

- Control valves shall be brass or stainless steel body, modulating (equal percentage characteristic), pressure-independent where possible, suitable for the HVAC system fluid, temperature, and pressure rating at Skardu conditions.
- Actuators for heating/cooling coil valves shall be spring-return, fail-safe type — fail to a defined safe position (open or closed as required) on loss of power or BMS signal.
- Damper actuators for outdoor air, exhaust air, zone control, and smoke control shall be direct-coupled, modulating 0–10 V or 2-position as required by the control sequence.
- All actuators shall provide position feedback signal (0–10 V or end-switch) to the BMS for monitoring and control loop verification.
- All actuators rated for continuous duty; minimum 50,000 cycle life; IP54 minimum.

PART 3 — EXECUTION

3.1 INSTALLATION

- BMS controllers shall be installed in dedicated, lockable, powder-coated steel control panels. Panel layout drawings shall be submitted for approval per Clause 1.5 before fabrication.
- All wiring within control panels shall be fully numbered with printed ferruled wire markers, neatly bundled with separate cable ducts for power wiring and signal/data wiring.
- All field wiring shall be run in dedicated conduit, separate from high-voltage power wiring. Minimum separation: 150 mm from 11 kV circuits; 50 mm from LV power circuits — per Electrical Design Report Section 2.
- All I/O field wiring shall be screened twisted pair (STP) cable. Cable screen shall be grounded at the controller panel end only (single-point earthing) to prevent ground loops.
- Conduit fill shall not exceed 40% of internal cross-sectional area for BMS/control cables. Pull boxes shall be provided per Clause 2.4.6 of the Electrical Design Report.
- All controllers shall be connected to a UPS capable of maintaining BMS operation for a minimum of 2 hours on loss of mains power.
- BMS network cabling shall be fully tested for continuity, crosstalk, and attenuation using a Category 6 field certification tester. Certificates shall be submitted to the Engineer.

3.2 PROGRAMMING AND COMMISSIONING

- All control sequences shall be programmed and individually tested offline by the BMS Contractor's qualified engineer before site acceptance testing (SAT) commences.
- Factory Acceptance Test (FAT): The Contractor shall conduct a complete FAT covering controller programming logic, graphic screen operation, and alarm annunciation at the BMS supplier's works. Engineer shall be invited minimum 2 weeks in advance per Electrical Design Report Clause 1.19.

- Site Acceptance Test (SAT): Point-by-point demonstration of all BMS input and output points, alarm functions, trending, and reporting in the presence of the Engineer. Written SAT record sheet to be completed and co-signed.
- Control loop tuning: All PID control loops shall be tuned on site under actual operating conditions with the building occupied/operational. Final tuning parameters shall be documented in the as-built CSO document.
- BMS graphic screens shall be reviewed by the Employer's representative after commissioning and revised as required at no additional cost before final acceptance.

3.3 TRAINING

The Contractor shall provide a minimum of three (3) days of on-site training for the Employer's designated operators and facility management staff, covering: system navigation and daily operation, alarm acknowledgment and response procedures, trending and energy reporting, basic controller re-programming for setpoint adjustment, fault-finding and diagnostic tools, and maintenance procedures. Training documentation in English and Urdu.

3.4 TESTING REQUIREMENTS

All testing shall be per Electrical Design Report Section 17, supplemented by the following BMS-specific tests:

Test Type	Acceptance Criterion
Insulation Resistance	$\geq 5 \text{ M}\Omega$ for all field wiring to earth — per Electrical Design Report Section 17
Network Communication Test	All BACnet objects respond correctly; packet loss $\leq 0.1\%$ over 1-hour test; latency $\leq 100 \text{ ms}$
Alarm Response Test	All alarm types generated (critical, high, medium, low); correct annunciation at OWS; email and SMS notifications verified
Trend Data Validation	Continuous 24-hour trend data integrity test; verify no data gaps; compare logged values against calibrated reference instruments
Fail-Safe Mode Test	Simulate controller failure (power removal); verify all output devices move to programmed fail-safe positions
Integration Tests	Solar PV data appears in BMS; generator alarms appear in BMS; UPS status visible; fire alarm integration (read-only) verified
Energy Meter Accuracy	BMS energy readings compared against certified reference meter; $\pm 1\%$ accuracy required

3.5 DOCUMENTATION

The following shall be delivered to the Engineer in both hard copy (3 sets, A3/A4 as appropriate) and electronic format (USB drive and PDF):

- As-built BMS drawings: point-by-floor panel wiring diagrams, BACnet network diagram, field device location plan (floor plans), I/O schedule with final tag numbers
- As-built points list with final BACnet address mapping, I/O type, engineering units, and setpoint values
- As-built Control Sequences of Operations (CSO) — marked up from submitted CSO to reflect any site changes
- Calibration records for all instruments (date calibrated, reference instrument used, as-found and as-left readings)

- Test and commissioning records (FAT, SAT sign-off sheets, loop test records)
- BMS software backup: controller programs, OWS database, graphic files, configuration — archived on USB drive
- Operations and Maintenance manuals for all equipment including replacement procedures

3.6 MEASUREMENT AND PAYMENT

The BMS shall be measured and paid as a lump sum per BOQ Item 12.01. The BOQ may be broken out into sub-items by system or by building area at the Employer's discretion. All civil works for conduit routing, cable trays, and control room modification are included unless separately itemised.

SECTION 0890 — INFORMATION TECHNOLOGY (IT) SYSTEMS

PART 1 — GENERAL

1.1 SCOPE OF WORK

This Section covers the complete design, supply, installation, testing, commissioning, and integration of all Information Technology (IT) Systems for the ATCT, Fire Station, and Allied Facilities at Skardu International Airport. Systems covered include:

- Structured Cabling System (SCS) — horizontal copper, backbone optical fibre, telecommunications rooms (MDF/IDF)
- Local Area Network (LAN) — Layer 2/3 managed switches, wireless access points (Wi-Fi 6)
- Wide Area Network (WAN) / Internet connectivity — interface provisions only
- Voice Over IP (VoIP) Telephone System — IP PBX / EPABX and handsets (BOQ Item 5.18)
- Uninterruptible Power Supply (UPS) for IT equipment — online double-conversion
- Server Room / Network Operations Centre (NOC) — racks, cooling, power infrastructure
- ATC Ground-Air Communication Infrastructure Provisions — passive conduit, earthing, antenna mounts only (primary ATC equipment is separate CAA/PANS procurement)
- Public Address (PA) and General Intercom System (BOQ Section 8)
- CCTV and Video Surveillance System (BOQ Section 7) — supplements Electrical Design Report Section 12
- Master Antenna Television (MATV) Distribution System

1.2 REFERENCE STANDARDS

Standard / Authority	Application
TIA-568.2-D	Balanced Twisted-Pair Telecommunications Cabling and Components
TIA-568.3-D	Optical Fiber Cabling and Components Standard
TIA-606-C	Administration Standard for Telecommunications Infrastructure
TIA-942-B	Telecommunications Infrastructure Standard for Data Centers
TIA-607-C	Generic Telecommunications Bonding and Grounding (Earthing)
ISO/IEC 11801 Ed.3	Generic Cabling for Customer Premises — Class EA / OM4 / OS2
ISO/IEC 14763-3	Implementation and Operation of Customer Premises Cabling — Testing
IEC 61300-3-35	Optical Fibre Connectors — End-face Inspection
IEEE 802.3	Ethernet Standard: 100BASE-T, 1000BASE-T, 10GBASE-T
IEEE 802.11ax	Wi-Fi 6 Wireless LAN Standard
IEEE 802.1Q	Virtual Bridged Local Area Networks (VLANs)
IEEE 802.3at	PoE+ Power over Ethernet (30 W)
ITU-T G.711	Pulse Code Modulation of Voice Frequencies — VoIP quality baseline
IEC 62368-1	Audio/Video, IT and Communications Equipment Safety
IEC 61000-4	Electromagnetic Compatibility — Testing and Measurement
ICAO Annex 10 Vol. II	Communication Procedures — Aeronautical Telecommunications

Standard / Authority	Application
ICAO Doc 9161	Manual on Frequency Assignment for Ground-Air Communications
Pakistan Telecom Authority (PTA)	Applicable Telecommunications Regulations
T&T Department NOC	NOC from Director General T&T, Ministry of Communications per Elec. Design Report Clause 1.26

1.3 GENERAL REQUIREMENTS

All IT systems shall be designed to meet the operational requirements of an ICAO-compliant Air Traffic Control environment. The following overarching requirements apply to all systems in this Division:

- Critical IT systems (LAN core, server room, VoIP PBX) shall incorporate N+1 redundancy as a minimum.
- All active IT equipment shall be powered through online double-conversion UPS systems providing minimum 60 minutes autonomy.
- The T&T Department NOC shall be obtained by the Contractor as required per Clause 1.26 of the Electrical Design Report before commencement of any telecommunications work.
- Wi-Fi access points shall NOT be installed within 10 m of ATC radio equipment rooms to prevent RF interference — coordinate installation locations with CAA/PANS.
- Server room / MDF shall be maintained at 18–24°C and 40–60% RH by dedicated precision air conditioning.
- All IT structured cabling shall be installed by a manufacturer-certified installer to qualify for the 25-year channel warranty.

1.4 SUBMITTALS

- Structured cabling design drawings: floor plans showing outlet locations, cable routes, TR/MDF/IDF locations, rack elevations
- Network architecture diagram: logical and physical topology, VLAN plan, IP addressing scheme, routing design
- Equipment data sheets for all active and passive IT equipment
- Server room / NOC detailed layout: power, cooling, cable management, rack configuration
- Factory test certificates and third-party performance test reports for all structured cabling components
- VoIP/PBX configuration design and dial plan
- UPS sizing calculations for all IT loads (kVA, runtime, de-rating at site altitude)
- IT security architecture document: firewall rules, network segmentation, access control matrix
- CCTV camera schedule and coverage diagram (floor plans with camera FoV overlays)
- PA system design with SPL calculations and EASE or equivalent simulation

1.5 CLIMATIC CONDITIONS

All IT equipment installed outside air-conditioned server rooms shall be rated for operation in the ambient conditions of Clause 1.7 of the Electrical Design Report (41°C max, -10°C min, 90% RH). Equipment in server rooms and MDF shall benefit from dedicated precision air conditioning maintaining 18–24°C.

1.6 GUARANTEE AND WARRANTY

Item	Warranty Requirement
Structured Cabling System — Channel	25-year end-to-end system warranty — manufacturer-backed; requires certified installer
Structured Cabling — Components	Manufacturer's standard product warranty (typically lifetime for passive components)
Active LAN / WAN Equipment	Minimum 5 years hardware warranty with next-business-day (NBD) advance replacement
VoIP PBX System	3 years hardware; 1 year software maintenance (extendable)
UPS Systems — IT	2 years on inverter/charger hardware; battery replacement per manufacturer's schedule (typically 3–5 years for VRLA)
CCTV System	2 years on all cameras, NVR, and accessories
PA System	2 years on all amplifiers, speakers, and accessories
Workmanship	12 months from issue of Completion Certificate per Contract Conditions

PART 2 — PRODUCTS

2.1 STRUCTURED CABLING SYSTEM (SCS)

2.1.1 Horizontal Cabling — Copper

Parameter	Specification
Cable Category	Category 6A (Cat6A), augmented; 10 Gbps capable; 500 MHz bandwidth
Cable Type	U/FTP (individually foil-shielded pairs) or F/UTP — as determined by detailed design; consistent throughout
Conductor	23 AWG solid copper; annealed; 100% copper — no CCA (Copper-Clad Aluminium) permitted
Jacket	HDPE primary insulation; CMR/LSZH outer jacket — Low Smoke Zero Halogen is MANDATORY for all areas within ATCT building
Fire Rating	IEC 60332-3-24 (flame retardant, limited fire spread); LSZH per IEC 60754-1 and IEC 60754-2
Maximum Horizontal Run	90 m permanent link + 10 m patch cords = 100 m total channel (per TIA-568.2-D)
Performance Standard	ISO/IEC 11801 Class EA; TIA-568.2-D Category 6A
Minimum Bend Radius	4× OD for patch cords; 8× OD for horizontal cable — never exceeded during or after installation
Maximum Pull Tension	110 N for 4-pair horizontal cable — pull tension gauge required
Test Requirement	100% channel certification per Level VI (or higher) field tester (e.g., Fluke DSX-8000); all parameters: wire map, length, IL, NEXT, PS-NEXT, ELFEXT, PS-ELFEXT, return loss, delay, delay skew, DC resistance — pass/fail report for every installed link submitted to Engineer
Acceptable Cable Brands	Belden, Panduit, Nexans, Brand-Rex, Draka, or approved equivalent with valid TIA/ISO test reports

Parameter	Specification
BOQ Quantities	Data cable 6,000 Rft (Item 5.05); Telephone cable 5,440 Rft (Item 5.05'); 1" dia. PVC conduit 5,362.5 Rft (Item 5.01)

2.1.2 Backbone Cabling — Optical Fibre

Parameter	Specification
Fibre Type (BOQ 5.07 — 1,200 Rft)	OS2 single-mode 9/125 µm for inter-building backbone; OM4 multimode 50/125 µm for intra-building backbone
Fibre Count	12 fibres per intra-building backbone; 24 fibres for main campus backbone — as per detailed design
Connectors	LC duplex (OM4 multimode); LC duplex APC (OS2 single-mode)
ODF (BOQ 5.08 — 1 No.)	24-port rack-mounted Optical Distribution Frame (ODF); front-access sliding drawers; fully populated with pre-terminated pigtails
SFP Modules (BOQ 5.06' — 10 No.)	Single-mode SFP; LC connector; Baynet or approved equivalent; compatible with installed LAN switches
Test Requirement	OTDR trace both directions at all operational wavelengths (850/1,300 nm for OM4; 1,310/1,550 nm for OS2); insertion loss per ISO 14763-3; end-face inspection per IEC 61300-3-35; all test results submitted
Underground Runs	Armoured cable; minimum 900 mm burial depth; sand bedding as per Electrical Design Report Section 8
Indoor Runs	Blown-in fibre through pre-installed duct preferred for long runs; or manual installation with proper support every 1 m in trays/conduit

2.1.3 Telecommunications Outlets and Floor/Tech Boxes

Component / BOQ Reference	Specification
RJ-45 Data Outlets (BOQ 5.03 — 75 No.)	Cat6A keystone jack; IDC tool-free or 110-type punchdown; 2-port faceplate minimum; flush wall-mounted; labeled per TIA-606-C; 300 mm AFF for workstation locations
RJ-11 Telephone Outlets (BOQ 5.04 — 68 No.)	IDC-type telephone keystone jack; 2-port faceplate; flush wall-mounted; labeled
Floor Boxes (BOQ 5.01' — 6 No.)	12 SWG die-cast aluminium; 10"×10"×4" depth; GI base box 16 SWG; 3 sets 15A PVC connectors; 1 data + 1 5A + 2 13A sockets per box; including floor-cutting
Tech Boxes (BOQ 5.02 — 62 No.)	Same as floor boxes but 15"×15"×4"; higher socket count per box
IPTV Outlets (BOQ 5.16 — 18 No.)	Cat6 UTP cable; RJ-45 faceplate (Orange/Clipsal/3M); 1" PVC conduit; in recreation, lounge, and briefing rooms

2.1.4 Telecommunications Rooms — MDF and IDF

Component	Specification
MDF / Server Room	Dedicated locked room; minimum 15 m² floor area for ATCT; 19" open racks or closed server cabinets; precision air conditioning N+1; raised access floor minimum 300 mm

Component	Specification
IDF Spaces	Per floor or building; minimum 2.4 m × 1.8 m dedicated lockable space; floor-mounted or wall-mounted racks
Racks / Cabinets (BOQ 5.13')	42U × 600 mm × 1,000 mm (D) 19" EIA steel network cabinets (1 No.); 12U cabinets (4 No.); 6U cabinets (2 No.); IP20; RAL7021; front/rear lockable doors; included in BOQ Item 5.14
Power in TR / MDF	Dedicated UPS-backed 15A/20A circuits per rack; smart metered PDU per rack
Cooling	Dedicated precision air conditioning; N+1 redundancy; 18–24°C; 40–60% RH
Cable Management	Horizontal and vertical cable managers per rack; blanking panels for all unused rack units
Earthing / Grounding	Dedicated Telecom Bonding Backbone (TBB) copper bus bar per TIA-607-C; bonded to building earth
Telephone DB (BOQ 5.10 — 1 No.)	100-pair; 20-pair Krone strips; patch cords (1 m and 3 m) — installed in IDF

2.2 LOCAL AREA NETWORK (LAN) — ACTIVE EQUIPMENT

2.2.1 LAN Switches

Parameter	Specification
Type	Layer 2 managed switch with PoE+ — 24-port
Uplink Ports	4× 10G SFP+ uplinks minimum per switch
Access Ports	24× 1G RJ45 PoE+ (IEEE 802.3at, 30 W per port) minimum
Switching Capacity	≥ 176 Gbps non-blocking switching fabric
PoE Budget	≥ 740 W per switch (sufficient for full 24 ports at 30 W)
Protocols	VLAN (IEEE 802.1Q), MSTP/RSTP, LACP (802.3ad), SNMP v3, RMON, SSH v2, RADIUS/TACACS+ authentication
Management	Web GUI; CLI via SSH; SNMP v3 trap; out-of-band management port; syslog
Redundancy	Dual redundant hot-swap power supplies; stacking or ring topology for N+1
Operating Temperature	0°C to +50°C
Certifications	CE, UL/CSA, RoHS, IPv6 ready
Acceptable Makes	Cisco Catalyst / Meraki, Juniper, Aruba / HPE, Huawei, or approved equivalent

2.2.2 Wireless LAN — Wi-Fi Access Points

Parameter	Specification
Wi-Fi Standard	IEEE 802.11ax (Wi-Fi 6) — dual-band 2.4 GHz and 5 GHz simultaneous
Throughput	≥ 1.8 Gbps aggregate per AP (5 GHz band) + 600 Mbps (2.4 GHz band)

Parameter	Specification
Simultaneous Clients	Minimum 100 concurrent clients per AP
Security	WPA3 Enterprise (802.1X / EAP-TLS); guest VLAN with isolation
Management	Cloud-managed or on-premise controller; centralised SSID, VLAN, and policy management; seamless roaming per 802.11r/k/v
Power	IEEE 802.3at PoE+ via LAN switch — no local PSU required
Coverage Design	Designed to provide minimum -65 dBm RSSI at all occupied areas; coverage map submitted to Engineer
Mounting	Ceiling-recessed or surface-mount; flush aesthetics in ATCT operational areas
ATC RF Safety Rule	APs shall NOT be installed within 10 m of ATC radio equipment rooms — coordinate with CAA; document in shop drawings
Acceptable Makes	Cisco Meraki, Aruba (HPE), Ubiquiti (enterprise UniFi), Huawei, or approved equivalent

2.2.3 Patch Panels and Cabinets

Component / BOQ Reference	Specification
Cat6 Patch Panels (BOQ 5.17 — 4 No., 24-port)	TIA/ANSI standard; Category 6 rated IDC punchdown; RJ-45 ports front; with integrated cable manager; Baynet or approved equivalent
Patch Cords (BOQ 5.12)	1 m (50 No.) and 3 m (25 No.); Cat6 UTP, factory-terminated, booted, colour-coded
PDUs (BOQ 5.15 — 8 No.)	Rack-mounted; 1× 10A/16A single cord; 1.5 kW minimum; ≥ 10 AC outlets per PDU; IEC/ANSI standard metered

2.3 VoIP TELEPHONE SYSTEM / EPABX

Supply, installation, and commissioning of an electronic PABX / IP PBX system:

Parameter	Specification
PABX System (BOQ 5.18 — 1 No.)	Electronic PABX; 4 trunk lines; 100 extensions minimum — VentiluxINC / Panasonic / Samsung or approved equivalent
System Capacity	100 SIP extensions (on-site BOQ baseline); expandable to 200 without hardware change
PSTN Interface	E1/PRI or SIP trunk via VoIP gateway; minimum 4 simultaneous PSTN calls
Extension Interfaces	2 multi-line executive telephone set interfaces
Operator Console	2-line LCD display; 15 programmable function keys; USB interface; powered from PABX
IP Handsets	Executive phones (colour display, 6 lines) for key ATCT and management staff; standard IP desk phones for general staff; per BOQ
DECT Wireless Handsets	For maintenance and fire station duty personnel — number per BOQ

Parameter	Specification
Emergency Analog Phones	Red loop-powered emergency phones for ATCT operational positions; connected via ATA adapter
Battery Backup	Maintenance-free batteries within PABX for minimum 2-hour power backup
Features	Auto-attendant, voicemail-to-email, call recording (ATC operational lines), conferencing, hot-standby failover, music-on-hold
Power	PoE-powered handsets per IEEE 802.3af/at via LAN switches; PABX server on UPS
Servo Stabiliser	Motor-controlled voltage stabiliser included
Compliance	PTA regulations; T&T Department NOC per Clause 1.26 of Electrical Design Report
Call Recording	All ATC operational line recordings retained for minimum 30 days

2.4 UNINTERRUPTIBLE POWER SUPPLY (UPS) — IT SYSTEMS

Parameter	Specification
Topology	Online double-conversion (VFI) per IEC 62040-3 — mandatory for all IT UPS
Configuration	N+1 parallel redundant UPS modules for main MDF/server room UPS; individual rack-mount UPS for IDF spaces
Autonomy — MDF / Server Room	Minimum 60 minutes at full rated IT load
Autonomy — IDF UPS	Minimum 30 minutes at full rated load
Output Power Factor	≥ 0.9 PF at rated output
Output Voltage	230 V AC single-phase 50 Hz; or 415 V 3-phase per rack PDU design as required
Battery Type	VRLA sealed maintenance-free (Valve Regulated Lead Acid); or Lithium-Ion preferred for longer life and reduced footprint
Communication	SNMP v1/v2c/v3 network management card; Modbus TCP/IP for BMS integration per Section 0880 of this document
Altitude De-rating	De-rating calculation for 2,228 m altitude submitted with submittal — confirm sizing is adequate after de-rating
Seismic Restraint	UPS installed with seismic restraints per BCP-SP-07 Zone 4
Standards / Certification	IEC 62040-3 (VFI classification), CE, RoHS
Acceptable Makes	APC (Schneider Electric), Eaton, Socomec, Vertiv, or approved equivalent

2.5 PUBLIC ADDRESS (PA) AND INTERCOM SYSTEM

Component / BOQ Reference	Specification
System Type	Digital networked PA — IP-based or conventional 100 V line audio distribution

Component / BOQ Reference	Specification
Coverage Zones	Minimum 5 zones: (1) ATCT Operations, (2) Fire Station, (3) Offices/Admin, (4) External/Apron areas, (5) Emergency — all zones simultaneous
Emergency Priority Override	Evacuation announcements automatically override all other channels; EN 54-16 compliant for life safety function
Speaker Wiring (BOQ 8.01 — 13 Zones)	PVC insulated, twin-core 2×1.23 mm ² , 300/500 V grade; separate shielded cable in dedicated 1" PVC conduit; zone-by-floor wiring
Wall Speakers (BOQ 8.02 — 13 No.)	15 W; 100 V line; surface or recessed mount; metal enclosure; aluminium grill; built-in 70/100 V transformer; SPL 92 dB (1W/1m) — max 99 dB; frequency response 130 Hz–13 kHz; EN 54 compliant
Outdoor Horn Speakers	IP65 rated; 30 W nominal; 100 V line; -20°C to +55°C; for external apron areas
Microphones (BOQ 8.03 — 2 No.)	Adjustable bidirectional; low distortion; suitable frequency response; at ATCT operations desk and fire station duty room
Power Amplifier 240 W (BOQ 8.04 — 1 No.)	Integrated rack-mount amplifier; backup amplifier provision; all accessories included
Power Amplifier 60 W (BOQ 8.05 — 1 No.)	Integrated; for smaller zones
Power Mixer (BOQ 8.06 — 1 No.)	For integration with existing PA system if required on site
PA PVC Conduit (BOQ 8.07 — 1,300 Rft)	1" diameter heavy duty PVC conduit; wall and slab-mounted
Intercom	Door video intercom at ATCT security entry (preferred); audio intercoms at main entrance, ATCT access doors, fire station

2.6 CCTV AND VIDEO SURVEILLANCE SYSTEM

The CCTV system shall comply with and expand upon Electrical Design Report Section 12. IP-based technology throughout — no analogue cameras:

Component / BOQ Reference	Specification
Indoor Dome IP Camera (BOQ 7.02 — 40 No.)	PoE; minimum 4 MP resolution; Day/Night mode; IR LED ≥ 20–30 m; Vandal-proof IK10; IP67; fixed lens; -30°C to +60°C; auto-heated housing for winter; mounting bracket included
Outdoor IP Camera (BOQ 7.03 — 32 No.)	PoE; minimum 4 MP; Day/Night; IP65; IR illumination ≥ 20–30 m; weather-resistant; mounting bracket
PTZ Camera (BOQ 7.04 — 4 No.)	360° pan/tilt/zoom; min. 4 MP; 32× optical + 16× digital zoom; Day/Night; Full HD 1080p; intelligent video analytics; speed dome housing
Joystick Controller (BOQ 7.05 — 1 No.)	For PTZ camera manual control at monitoring station

Component / BOQ Reference	Specification
NVR (BOQ 7.06 — 4 No.)	32-channel; 512 Mbps network throughput; 4K HDMI output; 12 MP max camera resolution; H.265+ compression; RAID-5 storage; Event trigger (alarm input, video loss); 16 TB HDD per NVR (minimum 90-day retention at all cameras full resolution)
VMS Software	ONVIF-compliant; minimum 3 simultaneous live-view workstations; remote access via encrypted VPN; motion detection, line crossing, intrusion zone, facial recognition option
NVR CPU Workstation (BOQ 7.07 — 1 No.)	Latest generation PC workstation for VMS client
CCTV Monitors (BOQ 7.10 — 3 No.)	4K LED 43" colour display; 2 HDMI 4K cables per monitor; wall bracket/VESA mount included
CCTV Integration Decoder (BOQ 7.11 — 1 No.)	256-channel decoder for integration with existing CCTV system if required
PoE Switches for CCTV (BOQ 7.08 — 4 No.)	24-port PoE+ Layer 2; D-Link / Huawei or approved equivalent; dedicated CCTV network switch
CCTV Patch Panels (BOQ 7.09 — 4 No. × 24-port)	24-port data patch panels; in CCTV rack / data cabinet
Cat6 Cabling (BOQ 7.01 — 11,400 Rft)	UTP Cat6 for PoE camera connections; in 1" PVC conduit (BOQ 7.13 — 11,400 Rft)
Storage Capacity	Minimum 20 TB RAID-5 protected per NVR group — expandable; 30-day full-resolution retention verified by test
Outdoor Camera Housing	IP67, IK10; auto-heated housing for Skardu winter conditions (-30°C operation)
Acceptable Camera Makes	Axis, Hanwha, Bosch, Dahua (IFS channel), Hikvision (IFS/BIS channel), or approved equivalent
System Warranty	2 years on all cameras, NVRs, and accessories

2.7 ATC GROUND COMMUNICATIONS INFRASTRUCTURE PROVISIONS

Provision	Specification
Conduit Provisions	Minimum four (4) runs of 50 mm HDPE conduit from the communications equipment room to ATCT cab level; pull string installed; both ends sealed after installation
Earthing Busbars	Dedicated copper earthing bus bars (300 × 50 × 6 mm) in the communications room; bonded to main earthing system per Electrical Design Report Section 16; earth resistance to main earth ≤ 0.5 Ω
Antenna Mounts	Hot-dip galvanised steel pipe mounts (50 mm dia., wall thickness ≥ 3 mm) with base flanges on ATCT cab roof; minimum four (4) positions for future antenna installations; structural loads verified by structural engineer

Provision	Specification
Dedicated Cable Trays	300 mm wide perforated galvanised steel cable trays in communications room and cab level — separate from IT LAN cable trays; labelled 'ATC COMMS — RESERVED'
Power Provisions	Dedicated 30A, 3-phase feeder from generator-backed DB; terminated in distribution board in communications room; circuits labelled and reserved for CAA equipment; circuits isolated and locked off until CAA installation
EMI Shielding	Communications room walls, floor, and ceiling lined with minimum 1 mm hot-dip galvanised steel sheet to form a Faraday cage; bonded to earthing busbar at minimum four (4) points per wall; all penetrations sealed with bonded glands

2.8 MASTER ANTENNA TELEVISION (MATV) SYSTEM

Parameter	Specification
Head End	Programmable satellite receiver/modulator; minimum 10 channels; installed in MDF room
Distribution	100 Ω coaxial tree-and-branch; RG-6 coaxial cable per Electrical Design Report Section 12; tap-off at each floor level
TV Outlets	F-type coaxial connectors; flush wall-mounted; in recreation room, lounge, and briefing rooms
Signal Level at Outlet	60–80 dB μ V at all outlets — verified by signal level meter at commissioning
Future Provision	Conduit stub-outs at all outlet boxes for future upgrade to fibre-based IPTV distribution

PART 3 — EXECUTION

3.1 INSTALLATION

Structured Cabling

- All structured cabling shall be installed by a manufacturer-certified installer — mandatory for 25-year channel warranty qualification.
- Cable routing: minimum 50 mm separation from 230 V power cables; minimum 150 mm from fluorescent or LED lighting fixtures (EMI per TIA-568.2-D).
- Cables shall never exceed minimum bend radius: 4 $\times$ OD for patch cords; 8 $\times$ OD for horizontal cable — enforced during and after installation.
- Pull tension shall not exceed 110 N for 4-pair horizontal cable. Pull tension gauge to be used on all cable runs.
- Telecommunications outlets installed per Electrical Design Report Section 4: 16 SWG sheet steel outlet boxes recessed in walls, with conduit entries; coordinate with BMS and electrical outlet locations.
- All conduit work for IT systems: comply with Electrical Design Report Section 2 — minimum 20 mm PVC conduit; pull boxes at $\leq$ 20 m; maximum 2 quarter-bends between pull points.

Optical Fibre

- Fibre optic cables: sweep radius $\geq$ 30 $\times$ OD at all bends. Fibre shall not be subjected to tensile load during installation — blown-in fibre preferred for all runs > 30 m.
- Fibre splices shall be fusion spliced only — no mechanical splices; average splice loss $\leq$ 0.1 dB.

Server Room / MDF

- All cable entry points through raised floor or slab shall be sealed with fire-rated intumescent putty or pillows after cable installation — fire compartmentalisation maintained.
- UPS systems installed on manufacturer-rated floor loading. Seismic restraints per BCP-SP-07 Zone 4 required on all UPS equipment.

3.2 TESTING AND CERTIFICATION

Test Category	Method and Acceptance Criterion
Copper Cabling — 100% Channel Certification	Level VI field tester minimum (Fluke DSX-8000 or equivalent); full suite per TIA-568.2-D: wire map, length, IL, NEXT, PS-NEXT, ELFEXT, PS-ELFEXT, return loss, propagation delay, delay skew, DC loop resistance, DC resistance imbalance; pass/fail report for every installed link — submitted to Engineer before acceptance
Optical Fibre Testing	OTDR trace both directions at all operational wavelengths (850/1,300 nm OM4; 1,310/1,550 nm OS2); insertion loss per ISO 14763-3; end-face visual inspection per IEC 61300-3-35 on 100% of connectors; all results submitted
LAN / Network Testing	VLAN segmentation verification (no inter-VLAN leakage); bandwidth and latency test (iperf3 or equivalent); PoE output power verification per IEEE 802.3at on all PoE ports
VoIP / PBX Testing	End-to-end call quality MOS ≥ 4.0 ; emergency line test to PSTN; call recording system verification; T&T NOC compliance verification
UPS Testing	Load bank test at 100% rated load for minimum 30 minutes; battery autonomy test at full IT load; SNMP/Modbus communication verification with BMS
CCTV Testing	Camera FoV verification against submitted coverage diagram on-site; 30-day recording continuity test; remote VPN access verification; analytics alarm function test (motion, intrusion zone)
PA System Testing	SPL measurement at minimum 3 representative points per zone using calibrated sound level meter; compare against EASE simulation; emergency override test; audio feedback/squeal test

3.3 LABELING AND DOCUMENTATION

All labeling shall comply with TIA-606-C throughout:

- Every cable, patch panel port, keystone jack outlet, and active equipment port shall be permanently labeled per the agreed labeling convention before acceptance.
- Cable labels: heat-shrink type or UV-resistant permanent adhesive for outdoor, machine-printed — no hand-written labels.
- All LAN equipment: asset tag and IP address label affixed to front panel.
- As-built drawing package shall include: floor plan cable routes, rack elevation diagrams, logical network diagram, VLAN map, IP address schema, Wi-Fi channel plan, CCTV camera FoV overlay, PA speaker layout — all in PDF and AutoCAD DWG-compatible formats on USB drive.

3.4 TRAINING

The Contractor shall provide minimum three (3) days of on-site training covering: LAN administration (VLAN management, switch CLI, Wi-Fi controller), VoIP PBX administration (extension programming, call routing, recording retrieval), NVR/VMS operation and video retrieval, UPS monitoring and battery maintenance, PA/intercom operation, and structured cabling documentation (how to read test reports and as-builts). Training materials in English and Urdu.

3.5 MEASUREMENT AND PAYMENT

IT systems shall be measured and paid per the Bill of Quantities, broken out as: structured cabling (per outlet/per linear run — BOQ Items 5.01–5.17); LAN equipment (per item — BOQ Items 5.11–5.14); VoIP/PABX system (lump sum — BOQ Item 5.18); CCTV system (per camera plus NVR lump sum — BOQ Items 7.01–7.14); PA system (lump sum — BOQ Items 8.01–8.07). All conduit work and civil works associated with IT systems are included unless separately itemised.

SECTION 0900 – AERONAUTICAL BEACON SYSTEM

PART 1 – GENERAL

1.01 GENERAL

A. Section Includes

This Section specifies requirements for the provision, installation, testing, and commissioning of a complete Aeronautical Beacon System at the Air Traffic Control Tower (ATCT) at Skardu International Airport, including all associated civil, electrical, and control works, as follows:

1. LED aerodrome beacon unit, complete with lamp, optical system, and weatherproof housing.
2. Beacon controller with integrated photocell and fault alarm relay.
3. ATC console remote control interface with activation buttons, status indication, and pilot relay contacts.
4. Power supply, UPS back-up, and all associated electrical distribution.
5. Power and control cabling in conduits with terminations and labelling.
6. Earthing system including earth electrode installation and bonding.
7. Lightning protection system in accordance with IEC 62305.
8. Reinforced concrete foundation, mounting structure, levelling, and alignment.
9. Pre-commissioning, operational testing, and ATC integration testing.
10. As-built drawings, O&M manuals, and commissioning certificate.

B. Related Sections

1. Section 0010 – General Requirements
2. Section 0150 – Concrete Works
3. Section 0620 – Earthing / Grounding System
4. Section 0490 – General Requirements for Electrical Works
5. Section 0530 – Low Tension Switchboards / LT Outdoor Distribution Boards
6. Section 0630 – Lightning Protection System
7. Section 0740 – CNS Equipment (ATC Systems Integration)

1.02 APPLICABLE STANDARDS AND REFERENCES

All work shall conform to the latest edition of the following standards, codes, and directives. In the event of conflict, the order of precedence shall be as listed:

Reference	Document Title / Application
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ICAO Annex 14 Vol. I	Aerodrome Design and Operations, 9th Edition – §4.7 Aerodrome Beacon; §8 Visual Aids for Navigation
ICAO Doc 9157	Aerodrome Design Manual, Part 4 – Visual Aids
ICAO Doc 9184	Airport Planning Manual
PAA Technical Directive	Pakistan Airports Authority Technical Directives for Visual Aids – latest issue
PCAA ANO-013	Pakistan Civil Aviation Authority Airspace and Aerodrome Standards
BCP-SP-40-2007	Building Code of Pakistan – Seismic Provisions (Seismic Zone 4)
BS EN 62305 / IEC 62305	Protection against Lightning (all parts)
IEC 61936-1	Power Installations Exceeding 1 kV AC – Earthing Systems
IEC 60529	Degrees of Protection Provided by Enclosures (IP Code)
IEC 60364	Electrical Installations of Buildings (all relevant parts)
IEC 60598-2	Luminaires – Part 2: Particular requirements
IEC 61000	Electromagnetic Compatibility (EMC)
BS 7430	Code of Practice for Protective Earthing
PEC Wiring Rules	Pakistan Engineering Council – Wiring Rules (current edition)
FIDIC Red Book	Conditions of Contract for Construction (MDB Harmonised Ed.)
PPRA Rules 2004	Public Procurement Rules – measurement and payment provisions

1.03 DEFINITIONS

Term	Definition
Aerodrome Beacon	A visual NAVAID exhibiting flashes of white (or alternating white and coloured) light to indicate the location of the aerodrome to aircraft, per ICAO Annex 14 §4.7.
Effective Intensity	The intensity of a fixed point light source that would produce the same visual effect as the flashing beacon, calculated per ICAO method (typically Blondel-Rey formula).
Flash Rate	Number of complete flash cycles per minute (fpm).
Photocell	Automatic daylight sensor controlling beacon ON/OFF switching based on ambient lux level.
Beacon Controller	Electronic unit controlling the flash rate, power regulation, fault detection, and remote interface of the beacon.
ATC Console Interface	Panel or sub-panel in the ATC working position providing remote ON/OFF activation and status monitoring of the beacon.

Pilot Relay	Relay contact within the controller providing a volt-free status signal for integration with the ATC system and/or airport management system.
Earthing System	Network of conductors and electrodes providing a low-impedance path to earth for fault current and lightning discharge.
LPL	Lightning Protection Level – classification (I through IV) per IEC 62305 indicating the probability of interception for lightning protection design.
AMSL	Above Mean Sea Level.
Engineer	The Engineer appointed by PAA under the Contract, or his authorised representative.

1.04 SUBMITTALS

A. Pre-Construction Submittals

The Contractor shall submit the following to the Engineer for review and approval not less than 28 days before commencement of works:

1. Product data sheets for beacon unit, controller, photocell, cabling, conduit, earthing electrodes, and lightning protection components – including manufacturer's catalogue numbers, certifications, and compliance statements against this Specification.
2. Earthing system design: electrode configuration, spacing, target resistance ($\leq 5 \Omega$), soil resistivity survey results, and calculation method per IEC 61936-1 Annex B.
3. Lightning protection design: risk assessment per IEC 62305-2, air termination layout, down conductor routing, bonding scheme, and SPD specifications.
4. Shop drawings: foundation plan, reinforcement detail, mast arrangement, cable routes, conduit layout, and ATC console interface panel arrangement.
5. Installation and testing methodology statement covering: sequence of civil and electrical construction activities; concrete curing programme with minimum 28-day hold before mast erection; mast erection method statement including crane or lifting equipment details and load calculations; cable installation and termination procedure; earthing system installation and sequential resistance test programme; and commissioning test programme with responsible persons named for each test activity.

B. Post-Commissioning Submittals (Closeout)

Within 30 days of successful commissioning, the Contractor shall submit:

1. As-built drawings (AutoCAD and PDF format): foundation detail, cable route plan, earthing layout, lightning protection layout, and ATC interface wiring diagram.
2. Complete Operation and Maintenance (O&M) Manual per Clause 1.07.
3. Manufacturer's type test certificate for the beacon unit confirming photometric output $\geq 2,000$ cd effective white-flash intensity at 2,230 m AMSL per ICAO Doc 9157 Part 4; calibration certificate for the photocell confirming ON/OFF switching thresholds as set and verified in the

final installed position at Skardu elevation; and beacon controller routine test certificate confirming functional compliance with all parameters specified in Clause 2.02.A.

4. Commissioning test records (complete test matrix with actual measured values).
5. Signed Commissioning Certificate per Clause 3.06.
6. Photometric measurement report with actual candela values measured at site.
7. Earth resistance test report (initial and post-backfill measurements).
8. Flash rate verification report.
9. Spare parts list with OEM part numbers and recommended quantities.

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications

1. The beacon unit shall be sourced from a manufacturer with a minimum of ten (10) years' demonstrated experience in the production of ICAO-compliant aeronautical beacons.
2. The manufacturer shall hold ISO 9001 (Quality Management) certification.
3. The manufacturer shall provide evidence of installations at a minimum of five (5) international airports, at least two (2) of which are at an elevation exceeding 2,000 m AMSL.

B. Installer Qualifications

1. Electrical installation works shall be carried out by a firm holding a valid PEC licence (Category EE or as applicable).
2. The lead installation engineer shall be a registered engineer with PEC and shall have experience of at least one (1) comparable aerodrome visual aid installation.
3. Civil works for foundation shall be supervised by a qualified Civil Engineer registered with PEC.

C. Regulatory Compliance

1. All works shall comply with PCAA ANO-013 and shall be subject to PCAA inspection and approval prior to activation.
2. The Contractor shall obtain all permits and clearances required by PCAA and PAA for installation and commissioning of the beacon system.

1.06 DELIVERY, STORAGE AND HANDLING

1. Equipment shall be delivered in original manufacturer's packaging with adequate protection against impact, moisture, and dust.
2. LED beacon heads and optical components shall be transported in shock-absorbing packaging; optics and lens assemblies shall not be stacked.
3. On-site storage shall be in a dry, clean, covered, and lockable store at or near the site office.

4. Temperature and humidity during storage shall remain within manufacturer's stated limits.
5. Cabling drums shall be stored upright on hard standing and shall not be stacked more than two (2) drums high.
6. Earthing materials (copper conductors, rods) shall be stored to prevent contamination that would impair electrical continuity.

1.07 OPERATION AND MAINTENANCE (O&M) MANUAL

The O&M Manual shall be submitted in both printed (two bound copies) and electronic (PDF) form and shall include, as a minimum:

1. System overview, functional description, and operating principles.
2. Component descriptions with manufacturer's data sheets and part numbers.
3. Normal operating procedure: power-up, activation, photocell override, ATC console remote control.
4. Fault identification and troubleshooting guide (with fault codes, causes, and corrective actions).
5. Preventive maintenance schedule including:
 - a. Monthly: Visual inspection, clean lens/reflector, check fixings.
 - b. 6-Monthly: Photocell threshold verification, controller functional test, earth resistance check.
 - c. Annually: Full photometric output measurement, flash rate verification, insulation resistance test, SPD inspection.
6. LED module replacement procedure (high-altitude safety precautions, work-at-height protocol).
7. Calibration procedure for photocell threshold.
8. Spare parts list with minimum on-hand inventory: LED module (1 No.), photocell (1 No.), controller PCB (1 No.), SPD modules (2 sets), fuses (1 set).
9. Wiring diagrams and cable schedules (as-built).
10. Health & Safety requirements (high-voltage warnings, working at height, lone-worker protocol).
11. Emergency shutdown procedure.

1.08 WARRANTY AND GUARANTEE

A. Equipment Warranty

1. The Contractor shall provide a manufacturer's warranty of not less than three (3) years from the date of the commissioning certificate for the beacon unit, controller, and photocell.
2. The LED module shall be warranted for a minimum service life of 50,000 hours at rated operating conditions.

3. The warranty shall cover replacement of defective parts and labour during normal working hours.

B. Installation Defects Liability

1. The defects liability period (DLP) for all installation works shall be twelve (12) months from the date of the commissioning certificate, in accordance with the Contract Conditions.
2. Any defect arising during the DLP which is attributable to defective materials, equipment, or workmanship shall be rectified at the Contractor's expense within 48 hours of notification for faults affecting beacon operability, and within 7 days for non-critical defects.

PART 2 – PRODUCTS

NOTE: All equipment performance parameters specified herein reflect Skardu site conditions (elevation 2,230 m AMSL). Manufacturers shall confirm in their technical submittals that stated performance is achievable at this altitude without derating, or shall provide derated values for Engineer's review.

2.01 LED BEACON UNIT

A. Type and Standard

1. The beacon shall be an aerodrome beacon of the rotating or directional (sequenced) type designed to produce the visual effect of flashing light, in full conformance with ICAO Annex 14, Volume I, §4.7 (Aerodrome Beacon).
2. The beacon shall be a high-intensity LED type; incandescent lamp units are not acceptable.
3. For Skardu International Airport (IFR capable airport): the beacon shall produce white flashes, or alternating white and green flashes if directed by the Engineer, at a flash rate of 20 to 30 flashes per minute.

B. Performance Parameters

Parameter	Requirement
Beacon type	ICAO aerodrome beacon – LED, rotating or electronically sequenced
Flash colour	White (alternating White/Green as directed by Engineer for IFR designation)
Flash rate	20 to 30 flashes per minute (fpm) – adjustable; factory-set at 24 fpm
Effective intensity (white)	≥ 2,000 candela (cd) effective intensity at site elevation (2,230 m AMSL)
Effective intensity (green)	≥ 200 cd effective intensity (if green flash specified)
Photometric calculation	Blondel-Rey method per ICAO Doc 9157, Part 4

Horizontal coverage	360° (full azimuth)
Vertical coverage	1° to 10° above horizontal plane (adjustable $\pm 1^\circ$)
LED drive current	Constant current; $\leq 80\%$ of rated maximum for thermal protection
LED colour temperature	$\geq 6,000$ K (white); CIE x/y coordinates within ICAO/IALA tolerance box
LED rated life	$\geq 50,000$ hours at rated conditions (L70 criterion)
Altitude correction	Performance figures certified at or corrected to 2,230 m AMSL; submit correction factor data

C. Mechanical and Enclosure Requirements

Parameter	Requirement
Drive mechanism	Brushless DC motor with optical encoder for position feedback (rotating type); or solid-state electronic sequencing (no moving parts preferred)
Enclosure protection rating	IP 66 minimum (IEC 60529); IP 67 preferred – for Skardu precipitation and snow ingress
Enclosure material	Marine-grade aluminium alloy or stainless steel; UV-stabilised polycarbonate lens/dome acceptable
Lens/dome material	Borosilicate glass or impact-resistant UV-stabilised polycarbonate; scratch-resistant coating
Mounting interface	Flanged base plate for bolted connection to mounting mast; stainless steel fasteners
Operating temperature	-30°C to $+55^\circ\text{C}$ (Skardu min recorded: -20°C ; include 10°C margin)
Storage temperature	-40°C to $+70^\circ\text{C}$
Wind loading design	Structural integrity up to 160 km/h wind speed (equivalent to 3-second gust at site)
Snow/ice load	Lens and housing designed to shed ice; no ice bridging across optical path
Weight	Submit; mounting structure shall be designed for actual beacon mass plus 25% dynamic factor
Colour finish	White or light grey; UV-stable, corrosion-resistant paint or anodising

D. Electrical Requirements – Beacon Head

Parameter	Requirement
Supply voltage (beacon head)	24 VDC or 48 VDC (SELV) from controller; or direct 230 VAC 50 Hz (as per selected manufacturer)
Power consumption	≤ 150 W (steady state, full intensity)
Power factor	≥ 0.90 at rated load
Thermal management	Active or passive cooling; LED junction temperature shall not exceed manufacturer's rated maximum at +55°C ambient
Surge protection	Integral SPD on power supply input: 6 kV/3 kA minimum per IEC 61643-11
EMC compliance	Compliant with IEC 61000-6-2 (immunity) and IEC 61000-6-3 (emission)

2.02 BEACON CONTROLLER AND PHOTOCELL

A. Controller

The beacon controller shall be a dedicated microprocessor-based unit, housed in a wall-mounted IP 54-rated steel enclosure, installed within the ATCT plant/equipment room. The controller enclosure shall be lockable and shall bear clear warning labels for high voltage.

Parameter	Requirement
Supply input	230 V AC ±10%, single phase, 50 Hz ±3%
UPS back-up	Integral or external UPS providing minimum 4 hours' continuous operation of beacon on mains failure; battery: VRLA type; auto-recharge on mains restoration
Output to beacon	As required by beacon head (24/48 VDC or regulated 230 VAC); stabilised, monitored
Flash rate control	Electronically programmable 20–30 fpm; factory-set 24 fpm; locked against unauthorised adjustment
Photocell input	Analogue or digital input from external photocell; configurable ON threshold and OFF threshold independently
Photocell hysteresis	Minimum 20% lux difference between ON and OFF switching thresholds to prevent hunting

Manual override	Key-switch for manual ON / AUTO / manual OFF; override shall be logged
Fault detection	Open-circuit LED/lamp fault, over-temperature, over-current, supply failure, UPS fault, photocell fault; each fault individually annunciated
Fault alarm output	Volt-free relay contacts (NO and NC), rated 5 A / 250 VAC, for each major fault category
Remote control input	Hardwired interface to ATC console (see Clause 2.03)
Status output to ATC	Volt-free contacts: BEACON ON, BEACON FAULT – minimum one (1) Form-C relay each
Data logging	Non-volatile event log: minimum 1,000 events with timestamp (fault, power cycle, manual override)
Operating temperature	0°C to +50°C
Enclosure IP rating	IP 54 (controller cabinet); IP 65 for any external control components

B. Photocell

Parameter	Requirement
Type	Solid-state silicon photodiode with temperature-compensated amplifier
Mounting	External, on ATCT roof or unobstructed external location – not shaded by building or beacon mast
ON switching threshold	Lux level at which beacon activates (sunset / overcast): adjustable 15–50 lux; factory-set 30 lux
OFF switching threshold	Lux level at which beacon deactivates (sunrise): adjustable 50–200 lux; factory-set 100 lux
Altitude note	At 2,230 m AMSL, solar irradiance is approximately 10–15% higher than at sea level; photocell shall be calibrated at site after installation
Response time	5 to 60 seconds (programmable); prevents false switching due to cloud transients
Spectral response	Photopic (CIE Standard Observer curve)
Enclosure IP rating	IP 66 minimum
Operating temperature	–30°C to +55°C
Cable	Shielded, outdoor-rated, UV-resistant 2-core (minimum) cable from photocell to controller

Fail-safe	On loss of photocell signal, controller shall switch to manual-ON or alarm, as configured – NOT to automatic OFF
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2.03 ATC CONSOLE REMOTE CONTROL INTERFACE

A. Interface Panel

A remote-control interface panel or sub-panel shall be provided for mounting in or adjacent to the ATC working position console (exact location to be confirmed with Engineer and Air Traffic Services before fabrication). Panel shall be clearly labelled 'AERODROME BEACON' in English, with professionally engraved or printed labels – no adhesive labels.

Parameter	Requirement
Panel material	Brushed stainless steel or anodised aluminium; minimum 2 mm thick
Panel finish	Consistent with existing ATC console aesthetics – submit sample for Engineer's approval
Activation switch	Illuminated push-button or key-switch: BEACON ON / OFF; green LED when ON, amber LED when FAULT
Status indicators	LED type: BEACON ON (green), BEACON FAULT (amber/red), MAINS FAIL (red), UPS ACTIVE (yellow)
Pilot relay activation	Dedicated push-button for pilot relay (where specified): 'PILOT ON/OFF'; with separate status LED
Indicator lamp voltage	≤ 24 VDC SELV – no mains voltage on ATC console panel
Wiring to controller	Hardwired shielded multi-core cable from ATC console to beacon controller in ATCT plant room
Cable routing	In dedicated signal cable conduit, segregated from power cables per IEC 60364-5-52
Interface polarity protection	All interface signals shall be protected against reverse polarity and short circuit

B. Pilot Relay

Where directed by the Engineer, a pilot relay shall be provided to output a volt-free contact signal indicating BEACON ACTIVE status for integration with the aerodrome management system or AFIS/ATC operations board. Relay rating: minimum 5 A / 250 VAC; Form-C contacts (NO + NC + COM). Pilot relay shall operate simultaneously with beacon activation; there shall be no manual-only relay activation without beacon energisation.

2.04 POWER AND CONTROL CABLING

A. Power Cable – Mains to Controller

Parameter	Requirement
Cable type	Armoured, copper conductor, XLPE/SWA/PVC (CU/XLPE/SWA/PVC) to BS 5467 / IEC 60502
Voltage rating	600/1000 V
Conductor size	Minimum 4 mm ² per phase (calculate for actual load with ≤ 3% voltage drop); not less than 4 mm ²
Armour	Galvanised steel wire armour (SWA)
Outer sheath colour	Black (power cable)
Short circuit rating	Calculated and stated in submittals

B. Output Cable – Controller to Beacon Head

Parameter	Requirement
Cable type	Armoured copper conductor, appropriate voltage rating for beacon supply type (SELV or 1000V rating)
Conductor size	As designed for actual current and voltage drop; minimum 2.5 mm ²
Armour	SWA; double-insulated where exposed above ground
UV resistance	UV-stabilised outer sheath for exposed sections

C. Control and Signal Cables

Parameter	Requirement
Cable type	Shielded, twisted pair, multi-core: OS/CY or equivalent to BS 5308 Part 2
Conductor size	Minimum 1.5 mm ² for control; 0.75 mm ² for signal pairs
Shield	Overall braided screen; drain wire provided; shield earthed at one end only (controller end)
Outer sheath colour	Grey (control/signal cable – distinct from power)
Cable identification	Each cable tagged at both ends with unique cable reference per cable schedule

D. Cable Installation Requirements

1. Underground cables shall be armoured type laid at minimum 600 mm depth in sand bedding, with cover tiles and warning tape.
2. All cables shall be installed in conduit – no direct-buried cables without conduit.
3. Maximum cable drum length without joint: cable runs from controller to beacon shall be continuous without intermediate joints unless approved by the Engineer.
4. Cable terminations shall use crimped copper lugs with heat-shrink sleeves; no bare twists.
5. All cable entries to enclosures shall use IP-rated cable glands appropriate to the enclosure IP rating.

2.05 CONDUIT SYSTEM

Parameter	Requirement
Type – underground	Rigid HDPE (high-density polyethylene) conduit, Class 450 N, minimum 50 mm ID; orange outer colour (electrical services)
Type – above ground / within building	Rigid galvanised steel conduit (GRC) to BS 4568; minimum 25 mm ID for control; 32 mm for power; threaded couplings
Fill ratio	Maximum 40% of conduit cross-sectional area occupied by cables
Bends	Factory-made long-radius bends (radius $\geq 8 \times$ conduit OD) – no site-bent conduit for underground runs
Draw wires	Polypropylene draw wire left in all conduit runs for future use
Separation	Power cables and signal/control cables in separate conduits with minimum 150 mm clear spacing (underground) and 100 mm (above ground)
Conduit supports – above ground	GRC conduit fixed to structure at maximum 1,200 mm spacing with approved saddles
Conduit sealing	Conduit ends at equipment entries sealed with approved fire-rated sealant or conduit plugs to prevent gas, moisture, or vermin ingress
Labelling	Conduit labelled at each end and at intermediate points at maximum 10 m intervals, with cable number and service

2.06 EARTHING SYSTEM

A. System Configuration

1. A dedicated earthing system shall be provided for the aeronautical beacon, bonded to the building main earthing terminal (MET) and to the lightning protection system.
2. The earthing system shall be designed to achieve a system earth resistance (R_{earth}) of $\leq 5 \Omega$ measured at the MET, per IEC 61936-1, Annex B.

3. If soil resistivity measurement confirms that $\leq 5 \Omega$ cannot be achieved with a conventional rod system, a counterpoise ring electrode or chemical electrode system shall be used, subject to Engineer's approval.

B. Earth Electrode

Parameter	Requirement
Type	Copper-bonded steel earth rods – minimum 17 mm diameter × 1,500 mm long; extensible
Minimum installation depth	1,800 mm below finished ground level
Number	Minimum 2 (two) rods in parallel; spacing $\geq$ twice rod length (3,600 mm minimum)
Conductor to rods	35 mm ² bare stranded copper conductor (hard-drawn); exothermic (Cadweld) or compression connections – no solder
Soil resistivity survey	Contractor shall conduct a Wenner 4-pin soil resistivity measurement prior to final electrode design; submit results with earthing design
Earth test point	Removable link earth test point provided at each electrode to allow individual resistance measurement
Corrosion protection	All underground connections protected with anti-corrosion bituminous tape and proprietary compound

C. Equipotential Bonding

1. The beacon mounting structure (mast/pedestal), controller enclosure, conduit system, and cable armour shall all be bonded to the earthing system with 25 mm² minimum green/yellow copper conductor.
2. Bonding connections shall be made with bolted or compression-type terminals; no twist connections.

2.07 LIGHTNING PROTECTION SYSTEM

A. Design Basis

1. The lightning protection system shall be designed in accordance with IEC 62305 (all parts), for Lightning Protection Level III (LPL III) as a minimum, or as determined by the risk assessment per IEC 62305-2 (whichever is more stringent).
2. Skardu is located in a region of moderate-to-high keraunic level (thunder-day frequency); Contractor shall obtain local meteorological data from PMD (Pakistan Meteorological Department) for Skardu and confirm LPL in the design submission.

B. Air Termination

1. The top of the beacon mast shall be treated as a terminal for natural air termination or an air terminal (Franklin rod) shall be provided 300 mm above the beacon head, so that the beacon lies within the protected zone per IEC 62305-3.
2. Air terminal: copper or stainless steel, minimum 16 mm² cross-section; secured against the wind loads specified.

C. Down Conductors

1. Minimum one (1) dedicated down conductor from air termination to earth electrode ring, run down the mast exterior in a straight vertical path where possible.
2. Conductor: 50 mm² copper flat tape or round conductor per IEC 62305-3.
3. Test joint with measurement clamp at 600 mm above ground level.

D. Surge Protection Devices (SPDs)

Parameter	Requirement
Location 1: Mains input to controller	Combined Type 1+2 SPD per IEC 61643-11; $U_p \leq 2.5$ kV; discharge current $I_{imp} \geq 12.5$ kA (10/350 μ s)
Location 2: Controller output to beacon cable (external)	Type 2 SPD; $U_p \leq 1.5$ kV; $I_{max} \geq 40$ kA (8/20 μ s)
Location 3: Signal cables from photocell and ATC interface	Type 2/3 signal SPD appropriate to cable type; $U_p \leq 80$ V (signal circuits)
SPD status indication	Visual indication (cartridge colour / LED) for blown condition; accessible for inspection without dismantling
Replacement SPD modules	Two (2) complete replacement sets of each SPD type to be provided as part of the spare parts kit

2.08 FOUNDATION AND MOUNTING STRUCTURE

A. Foundation

1. A reinforced concrete (RC) foundation shall be designed and constructed specifically for this beacon installation, taking account of all applicable loads.
2. The foundation and mounting structure shall be structurally designed to resist the following simultaneous design actions
 - a. Seismic Zone 4 per BCP-SP-40-2007 (design PGA 0.40g at Skardu).
 - b. Design wind speed 160 km/h (3-second gust) per ICAO Doc 9157 and local meteorological data.
 - c. Snow load per IS/BS applicable standard for Skardu conditions (reference PMD Skardu snow depth records).
 - d. Dead load of beacon + mast + ancillaries with a minimum 25% dynamic magnification factor.

3. Foundation dimensions, reinforcement, and concrete grade shall be shown on approved shop drawings.
4. Concrete works shall comply with Section 0150 – Concrete Works of this Volume.
5. Anchor bolts: stainless steel Grade 316, sized per structural design; installed with bolt templates during concrete pour.
6. Foundation top surface: levelled to ± 2 mm in any 1,000 mm using a precision levelling instrument; bearing surface clean and free from irregularities.

B. Mounting Mast / Pedestal

Parameter	Requirement
Material	Hot-dip galvanised structural steel (S275 or S355) or marine-grade aluminium alloy 6061-T6
Height above finished ground / roof level	As per drawings and ICAO Annex 14 §4.7 siting requirements; Engineer's approval required
Surface treatment	Hot-dip galvanised and painted white or light grey; UV-stable 2-pack epoxy topcoat; minimum total DFT 250 μm
Cable access	Watertight cable entry point at base; internal cable duct or surface channel to beacon head; rodding eye at bends
Access for maintenance	If mast height > 3 m: provide fall-arrest anchor point; if height > 6 m: fixed ladder with safety cage per EN ISO 14122
Levelling	Adjustable base plate with levelling bolts; final levelled and grouted with non-shrink epoxy grout
Vibration isolation	Anti-vibration pads between mast base plate and foundation where rotating beacon is used

PART 3 – EXECUTION

3.01 EXAMINATION AND PRE-WORK CONDITIONS

1. Before commencing work, the Contractor shall inspect and confirm: proposed beacon location is consistent with ICAO Annex 14 §4.7 siting criteria (unobstructed 360° horizontal visibility, not in OLS surfaces, not within restricted areas requiring additional clearance); coordinate with Engineer and PCAA to confirm siting is approved.
2. Soil conditions at the proposed foundation location shall be inspected; if unsuitable bearing material is encountered, notify the Engineer immediately.
3. Existing underground services at the cable route shall be identified and located using a cable/pipe detection survey. The Contractor assumes responsibility for any damage to unmarked services if this survey has not been completed.

4. The Contractor shall verify that the mains power supply available at the ATCT switchboard is adequate for the beacon controller connection (circuit rating, RCD protection, isolator).
5. No work shall proceed until the Engineer confirms the inspection as satisfactory in writing.

3.02 FOUNDATION AND MAST INSTALLATION

A. Foundation Works

1. Excavate to the dimensions and levels shown on the approved shop drawings.
2. Compact sub-grade to 95% Modified Proctor density; notify Engineer for inspection before blinding layer.
3. Blinding layer: 75 mm C10 lean concrete on undisturbed formation.
4. Install reinforcement cage per structural drawings; maintain minimum 50 mm cover on all sides; cover spacers shall be plastic, not timber.
5. Set anchor bolt template to exact plan position and plumb with a spirit level; check and lock before concrete pour.
6. Place and vibrate C25/30 concrete; cure for minimum 7 days before any load application; cure for 28 days before mast erection.
7. Concrete test cubes: take minimum one (1) set of three (3) cubes per pour; test at 7 and 28 days; submit results to Engineer.

B. Mast Installation and Alignment

1. Erect mast on anchor bolts with correct washers and nuts; do not tighten fully until levelling is verified.
2. Level the mast to within $\pm 0.1^\circ$ of vertical (plumb) in two orthogonal planes using a precision spirit level or digital inclinometer.
3. Once levelled, tighten anchor bolts to specified torque (per structural design); apply thread-locking compound.
4. Fill void under base plate with non-shrink epoxy grout; allow to cure before applying full load.
5. Apply sealant bead around perimeter of base plate to exclude water.

C. Beacon Head Mounting and Alignment

1. Mount beacon head on mast per manufacturer's installation instructions.
2. Connect all cables before final tightening of beacon mounting bolts.
3. Level/align beacon head per manufacturer's instructions such that the optical beam centre is directed as required; check vertical angle of beam centre (target: $2-5^\circ$ above horizontal for typical airport configuration – confirm with Engineer).
4. Apply anti-seize compound to all stainless fasteners.

5. Do not leave beacon lens/dome uncovered during installation; reinstall all covers and seals before any test.

3.03 EARTHING AND LIGHTNING PROTECTION INSTALLATION

1. Drive earth rods vertically at approved locations; do not use hammers that will distort the rod coupling threads.
2. Make all underground connections by exothermic welding (Cadweld or approved equivalent); inspect and photograph each connection before backfilling.
3. Measure earth resistance of each rod individually before connection to ring, and of the complete system after connection – record all values.
4. If system resistance exceeds 5 Ω , install additional rods or a deep-driven rod until target is achieved; notify Engineer before backfilling.
5. Backfill trenches in layers of maximum 150 mm; compact each layer. For rods in rocky ground, use approved low-resistivity soil enhancement compound (bentonite or equivalent) to reduce contact resistance.
6. Install all bonding conductors; make bonding connections before installing SPDs.
7. Install SPDs as specified in Clause 2.07.D; connect in accordance with manufacturer's instructions and IEC 62305-3 for separation distances from main conductors.
8. Install air termination and down conductor; fasten with approved copper or stainless-steel cleats at maximum 1,000 mm spacing.
9. After full system installation, perform final earth resistance measurement and record; submit test certificate.

3.04 CABLING AND CONDUIT INSTALLATION

1. Install all conduit before pulling cable; prove each conduit run by rodding through with the largest mandrel specified.
2. Lay underground HDPE conduit in clean sand bedding (150 mm below, 150 mm above); cover tiles and orange warning tape at 300 mm above conduit.
3. Pull cables with a calibrated pulling grip; maximum pulling tension shall not exceed cable manufacturer's stated limit.
4. Provide minimum 10% spare length (slack loop) at each termination point.
5. Terminate all conductors with appropriate copper lugs; crimp with a ratchet crimping tool. No open twist connections.
6. Apply heat-shrink insulation sleeves over crimp lugs; label each terminal per the wiring schedule.
7. Megger test all power cables at 500 V DC before connection to equipment; minimum insulation resistance: 100 M Ω ; record all values.

8. Megger test all control/signal cables at 250 V DC; minimum insulation resistance: 100 MΩ; record all values.
9. Cable screen (shield) shall be earthed at the controller end only (single-point earthing); insulate screen at the remote end.
10. After termination, continuity test each cable core; verify polarity at both ends.
11. Apply permanent cable tags at both ends of each cable; tags to be stainless steel or UV-stable nylon, engraved or UV-printed – no hand-written or adhesive labels.

3.05 CONTROLLER, PHOTOCELL, AND ATC INTERFACE INSTALLATION

1. Mount controller cabinet on approved wall brackets in the designated plant/equipment room of the ATCT; height of work-access 1,200–1,500 mm above finished floor level for the main operating controls.
2. Controller cabinet shall be fixed with anti-vibration mounts where structure-borne vibration is possible from HVAC equipment.
3. Mount photocell on external bracket in a location with clear view of sky, unshaded from sunrise to sunset, and inaccessible to casual tampering.
4. Route photocell cable in weatherproof conduit from photocell to controller; conduit entry to controller via an IP-rated cable gland.
5. Install ATC console interface panel at the agreed location within the ATC working position; route control cable in dedicated trunking or conduit, clearly labelled and segregated from other cables.
6. After installation, verify correct polarity and cable identity at all termination points before energising.

3.06 PRE-COMMISSIONING, OPERATIONAL TESTING, AND ATC INTEGRATION TESTING

A. Pre-Commissioning Checks

Before energising, the Contractor shall complete and record all of the following:

Test / Check	Acceptance Criterion
Insulation resistance – power cables	≥ 100 MΩ at 500 V DC
Insulation resistance – control cables	≥ 100 MΩ at 250 V DC
Cable continuity and polarity	Zero resistance path; correct polarity at both ends
Earth resistance – individual rods	Record actual value (informational)

Earth resistance – complete system	$\leq 5 \Omega$
Bonding continuity	$< 0.1 \Omega$ between beacon base and MET
Mast plumb / vertical alignment	$\leq 0.1^\circ$ deviation in both planes
Beacon head optical alignment	Beam centre 1° – 10° above horizontal (verify with inclinometer)
Conduit installation and sealing	All conduit entries sealed; warning tape installed
SPD installation check	All SPD modules installed; cartridges intact; connections per manufacturer's drawing
Controller wiring check	All terminals correctly labelled; connections per wiring schedule

B. Operational Commissioning Tests

1. **Initial Energisation:** Apply mains power under supervision; verify no earth faults, no tripped circuit breakers, no blown fuses; measure supply voltage at controller input terminals and record.
2. **Beacon start-up:** Activate beacon via ATC console; verify beacon illuminates within 5 seconds of activation command; record start-up time.
3. **Flash rate verification:** Using a calibrated photometer or stroboscope, measure flash rate over a minimum 3-minute period; record value – acceptable range: 20–30 fpm (factory set: 24 fpm ± 1 fpm).
4. **Photometric output measurement:** Using a calibrated luminance meter / illuminance meter at a known distance (minimum 100 m), measure effective intensity of white beam; correct to 2,230 m AMSL atmospheric conditions per ICAO Doc 9157 §4.3 – minimum acceptable effective intensity: 2,000 cd.
5. **360° coverage check:** Conduct azimuth sweep (minimum 8 measurement positions at 45° intervals) to confirm uniform 360° coverage with no dark sectors exceeding 10° arc.
6. **Photocell auto-switching test:** Cover photocell with opaque material (simulate darkness); verify beacon activates automatically within the programmed response time. Remove cover; verify beacon deactivates. Record switching lux thresholds.
7. **Manual override test:** Test manual-ON and manual-OFF key-switch functions independently of photocell; verify correct operation.
8. **Fault alarm test:** Disconnect beacon head supply cable at controller (simulate open-circuit fault); verify fault alarm relay operates; verify alarm indication at ATC console within 5 seconds.

9. **UPS/battery backup test:** Isolate mains supply to controller; verify beacon continues to operate on UPS backup power; verify UPS ACTIVE indication at ATC console; measure actual backup duration – minimum required: 4 hours continuous operation at full load; record measured duration.
10. **Mains restoration test:** Restore mains supply; verify beacon remains ON and UPS commences recharge; verify no interruption to beacon during changeover.
11. **72-Hour Soak Test:** Operate beacon continuously in AUTO (photocell) mode for a minimum of 72 hours; Engineer to inspect at commencement and at conclusion; record any faults or anomalies.

C. ATC Integration Testing

1. With ATC console interface connected and powered: verify all status indicators on the ATC panel operate correctly (BEACON ON, BEACON FAULT, MAINS FAIL, UPS ACTIVE).
2. Test each ATC console activation button for correct beacon response.
3. Test pilot relay operation: activate beacon from ATC console; verify pilot relay closes and status is correctly output to the aerodrome management system or ATC operations board (as applicable); verify relay opens when beacon deactivates.
4. With a representative from Air Traffic Services present: conduct a walk-around visibility test, confirming beacon is visible from all traffic circuit positions and approach areas.
5. The Engineer and PAA/ATC representative shall sign the Integration Test Record before the commissioning certificate is issued.

D. Commissioning Certificate

The commissioning certificate shall be issued by the Engineer upon successful completion of all pre-commissioning checks, operational tests, and ATC integration tests. The certificate shall record:

1. Date of commissioning.
2. Identification of all equipment installed (manufacturer, model, serial numbers).
3. Summary of all test results with actual measured values versus acceptance criteria.
4. List of any outstanding items (if any) with agreed completion dates – no major items shall remain open.
5. Signatures: Contractor, Engineer, PAA Representative, ATC Representative.

3.07 ADJUSTING AND ALIGNMENT VERIFICATION

1. After the 72-hour soak test, re-verify beacon head alignment with an inclinometer; re-level if any settlement has occurred.
2. Re-verify photocell lux threshold calibration in the final installed position in daylight; adjust if required.
3. Confirm all cable labels and conduit labels are still legible and correctly positioned after construction activity; replace any damaged labels.

3.08 CLEANING

1. Clean beacon lens/dome and optical surfaces with manufacturer's approved cleaning solution immediately before commissioning photometric test.
2. Remove all construction debris, packaging, and waste material from the installation area.
3. Touch up any damaged paint or galvanising on mast/structure before handover.
4. Verify all waterproof seals and gaskets are undamaged and correctly seated.

3.09 MEASUREMENT AND PAYMENT

A. Measurement

The aeronautical beacon system shall be measured as a single lump-sum item (1 No. – Complete System) and shall be deemed to include all works described in this Section and all associated incidentals. No separate measurement shall be made for the following, which shall be included in the rate:

1. All excavation, backfill, reinstatement, and disposal.
2. Concrete blinding, foundation (RC), and curing.
3. Anchor bolts, levelling bolts, epoxy grout, and sealants.
4. Mast / pedestal, access provisions, and anti-corrosion treatment.
5. Beacon head, controller, photocell, and ATC console interface panel.
6. All cabling, conduits, cable glands, lugs, labels, and trays.
7. Earthing system and lightning protection system (including SPDs and spare SPD sets).
8. All pre-commissioning tests, operational tests, ATC integration tests, and 72-hour soak test.
9. All submittals including shop drawings, test certificates, as-built drawings, O&M manuals, and commissioning certificate.
10. All permits, clearances, inspection fees, and PCAA coordination.
11. Spare parts kit as specified in Clause 1.07.
12. All temporary works, scaffolding, tools, and equipment necessary for installation.

B. Payment

Payment shall be made against the contract BOQ item rate as a single lump-sum. Interim payments may be approved by the Engineer in the following approximate proportions:

SECTION 0910 – AIRPORT CRASH ALARM AND EMERGENCY ALERTING SYSTEM

PART 1 – GENERAL

1.01 SUMMARY

A. Section Includes

This Section specifies the design, supply, installation, testing, and commissioning of a complete Airport Crash Alarm and Emergency Alerting System (hereinafter 'the System') for the Air Traffic Control Tower (ATCT) and Aircraft Rescue and Fire Fighting (ARFF) Station at Skardu International Airport, Gilgit-Baltistan, Pakistan.

The System shall provide immediate, reliable multi-modal (audible and visual) alerting to all ARFF personnel and vehicles upon receipt of any declared aircraft emergency or accident, conforming to the alerting standards and response-time objectives prescribed by ICAO Doc 9137 Part 1 and FAA Advisory Circular 150/5210-7D.

Work under this Section includes but is not limited to:

1. Crash Alarm Control Panel (CACP), including built-in uninterruptible power supply and battery backup.
2. Crash alarm push-button initiation stations at the ATC Tower Watch Supervisor Console and at crash-gate locations.
3. Electronic hooters, sirens, and crash bells at the ARFF appliance bays, watch room, dormitory, and external facade.
4. Amber stroboscopic visual alarm beacons at ARFF station interior and exterior locations.
5. Dedicated direct-line crash telephone (hotline) between the ATC Tower and the ARFF Station Watch Room.
6. Remote annunciator panel at the ATC Tower base lobby.
7. All associated conduit, cable, junction boxes, supports, labelling, earthing, testing, documentation, and commissioning.

B. Related Sections

1. Section 0010 – General Requirements
2. Section 0150 – Concrete Works
3. Section 0620 – Earthing / Grounding System
4. Section 0490 – General Requirements for Electrical Works
5. Section 0530 – Low Tension Switchboards / LT Outdoor Distribution Boards
6. Section 0740 – CNS Equipment
7. Section 0660 – Intelligent Addressable Fire Alarm System
8. Section 0500 – Low Voltage Diesel Generator Set

9. Section 0570 – Uninterruptible Power Supply (UPS) System
10. Section 0590 – Low Tension Cables
11. Section 0610 – Conduits and Pipes
12. Section 0630 – Lightning Protection System
13. Section 0780 – Voice Alarm and Public Address System
14. Section 0820 – Automatic Fire Detection System (AFDS)
15. Section 0880 – Building Management System (BMS)
16. Section 0900 – Aeronautical Beacon System

1.02 REFERENCES

The following standards and codes shall apply to the latest edition in force at the date of tender, unless a specific edition is cited. In case of conflict, the more stringent requirement shall govern. Where ICAO Standards and Recommended Practices (SARPs) conflict with any national or British standard, the ICAO SARPs shall prevail for aerodrome-safety-critical systems.

Standard / Code	Title / Description
ICAO Doc 9137 Part 1	Airport Services Manual – Rescue and Fire Fighting
ICAO Annex 14 Vol. I	Aerodromes – Aerodrome Design and Operations
ICAO Doc 9157 Part 4	Aerodrome Design Manual – Visual Aids
FAA AC 150/5210-7D	Aircraft Rescue and Fire Fighting Communications
FAA AC 150/5220-4B	Water Supply Systems for Aircraft Fire and Rescue Protection
NFPA 72	National Fire Alarm and Signaling Code (Latest Edition)
NFPA 403	Standard for Aircraft Rescue and Fire Fighting Services at Airports
NFPA 101	Life Safety Code
BS EN 54-1	Fire Detection and Fire Alarm Systems – Introduction
BS EN 54-2	Fire Detection and Fire Alarm Systems – Control and Indicating Equipment
BS EN 54-16	Fire Detection and Fire Alarm Systems – Voice Alarm Control & Indicating Equipment
IEC 60849	Sound Systems for Emergency Purposes
IEC 60529	Degrees of Protection Provided by Enclosures (IP Code)
BS 5839 Part 1	Fire Detection and Fire Alarm Systems for Buildings
IEEE Std 446	Recommended Practice for Emergency and Standby Power Systems

BCP 2021	Building Code of Pakistan – Seismic Provisions (Seismic Zone 4)
Pakistan Electricity Act 1910 / Rules 1937	Local Electrical Regulatory Requirements
IEE Wiring Regulations	Institution of Electrical Engineers Wiring Regulations (Latest)

1.03 DEFINITIONS

1. **ARFF:** Aircraft Rescue and Fire Fighting, as defined in ICAO Doc 9137 Part 1.
2. **ATC:** Air Traffic Control. For this project, refers to the new ATCT at Skardu International Airport.
3. **Crash Alarm:** An audible and/or visual signal activated to alert ARFF personnel to an aircraft emergency or accident requiring an immediate emergency response.
4. **Crash Bell / Hooter:** Generic terms for the electromechanical bell (motorised gong) or electronic sounder (siren/hooter) that generates the crash alarm audible signal.
5. **CACP:** Crash Alarm Control Panel – the central supervisory unit that monitors alarm inputs, executes alarm logic, activates all outputs, and provides status indication.
6. **Direct-Line (Crash) Telephone:** A dedicated, permanently-connected telephone circuit (hotline) between the ATC Watch Supervisor position and the ARFF Watch Room. No dialling is required; lifting the handset initiates connection.
7. **Level of Protection (LoP):** The ICAO ARFF category assigned to the aerodrome (Level 4 assumed for Skardu; to be confirmed by PAA/CAA). The System shall be scalable for higher LoP.
8. **LSZH:** Low-Smoke, Zero-Halogen – cable jacket compound producing minimal smoke and no halogenic gases when exposed to fire.
9. **Engineer:** The Engineer or his duly authorised representative appointed by the Employer under the Contract.

1.04 SYSTEM DESCRIPTION

A. Functional Overview

1. The System shall be a self-contained, supervised, dedicated aerodrome crash-alarm installation entirely separate from the building fire detection and alarm system. It shall not share field devices, cabling, or control panels with the NFPA 72 building fire alarm system specified under Section 0660 – Intelligent Addressable Fire Alarm System.
2. Upon activation of any initiation device, the CACP shall simultaneously and within three (3) seconds:
 - a. Activate all audible alarm devices (hooters, sirens, and crash bells) at the ARFF Station.
 - b. Activate all visual strobe beacons at the ARFF Station.
 - c. Illuminate all alarm-level LED indicator lamps and text annunciators on the CACP and on the remote annunciator panel.
 - d. Record the event in the non-volatile event log with date, time, initiating device identity, and alarm level.

- e. Transmit a dry-contact (volt-free) output for integration with the BMS for supervisory monitoring.

B. Alert Levels

The System shall support the following graduated alert levels in accordance with ICAO Doc 9137 Part 1, Section 2, and FAA AC 150/5210-7D. Each level shall produce a distinctive audible tone sequence and distinct LED colour coding as tabulated below.

Alert Level	Definition	ARFF Action Required
STANDBY	Aircraft in distress (precautionary); ATC notified. One (1) alarm tone pulse.	ARFF crew at stations, vehicles ready
LOCAL STANDBY	Aircraft experiencing non-critical difficulty; ARFF vehicles move to designated hold points.	Vehicles staged at runway threshold
FULL EMERGENCY	Aircraft has declared emergency; potential crash or overrun imminent.	All ARFF vehicles respond; crash gates open
AIRCRAFT ACCIDENT	Aircraft has crashed on or near the aerodrome.	Maximum response; mutual aid activated
ALL CLEAR / CANCEL	Emergency resolved; stand down all ARFF units.	Return to station; log entry required

Audible differentiation between alert levels shall be achieved by the following tone sequences, programmable via the CACP operator interface:

1. STANDBY: One (1) continuous 3-second tone burst, repeated at 30-second intervals.
2. LOCAL STANDBY: Two (2) alternating tone bursts (whoop-whoop), repeated continuously.
3. FULL EMERGENCY: Continuous fast-rate warble tone (Hi-Lo, 600/1000 Hz), no interruption.
4. AIRCRAFT ACCIDENT: Continuous fast-rate warble tone plus manual PA voice announcement capability activated on same channel.
5. ALL CLEAR / CANCEL: Three (3) short beeps followed by silence; automatically silences all audible outputs.

C. Initiation Points

Alarm initiation shall be possible from the following points:

1. ATC Watch Supervisor Console (primary initiation): Dedicated crash alarm push-button panel, key-switch protected, located within immediate reach of the Watch Supervisor.
2. Crash Gate Stations: Remote push-button stations at each manned or remotely supervised crash gate to allow ground observers to initiate an alarm.
3. Direct-Line Crash Telephone: Lifting the ARFF Watch Room crash telephone handset shall automatically illuminate an incoming-call indicator at the ATC Tower; the ATC Watch Supervisor may verbally declare the alarm level, which the ARFF crew then inputs to the CACP.
4. Manual Override at CACP: The ARFF Watch Room Officer-in-Charge shall be able to initiate or escalate any alarm level directly at the CACP front panel, independent of ATC.

D. System Supervision

1. The CACP shall continuously monitor all field device circuits for open-circuit, short-circuit, and ground-fault conditions. Any fault shall generate a distinct FAULT indication (amber LED + audible buzzer) at the CACP and at the remote annunciator panel, without initiating an alarm.
2. A daily automated self-test shall be programmable to activate each output device for two (2) seconds between 08:00 and 08:30 local time, with all events recorded in the log. Manual self-test shall also be available at all times.

1.05 SUBMITTALS

Within 28 days of award, the Contractor shall submit the following for the Engineer's review and approval before procurement or installation commences:

1. Detailed system design drawings including single-line block diagram, riser/schematic diagram, device location plan overlaid on architectural drawings, and conduit routing plan.
2. Equipment data sheets and manufacturers' catalogues for all components, cross-referenced to the equipment schedule in Clause 2.01.
3. Cable schedule identifying cable type, size, route, and length for every circuit.
4. Alarm tone sequence programming proposal for Engineer's approval against ICAO Doc 9137 criteria.
5. Battery sizing calculation demonstrating 24-hour standby plus 30-minute full-alarm capacity per NFPA 72 Chapter 10.
6. Acoustic calculation confirming audible levels in all occupied ARFF spaces meet the 15 dB above ambient margin.
7. Manufacturer's type test and routine test certificates demonstrating conformance to: EN†54-2 (CACP control and indicating equipment), EN†54-3 (electronic hooters and sirens), EN†54-23 (strobe visual alarm beacons), BS 5839 Part 1 (crash bells), and IEC†60849 (crash telephone circuit). Each certificate shall be cross-referenced to the corresponding item in the Equipment Schedule (Clause 2.01.A).
8. Commissioning and testing plan including pre-commissioning checks, functional test matrix, and acceptance test procedures.
9. Operation and Maintenance (O&M) manuals – draft prior to commissioning, final within 14 days of acceptance.
10. As-Built drawings on reproducible media and in AutoCAD/DWG format – submitted prior to final payment.

1.06 QUALITY ASSURANCE

1. The Contractor shall be a licensed electrical contractor authorised under the Electricity Act 1910 and Electricity Rules 1937 of Pakistan.
2. The crash alarm system installer shall have a minimum of five (5) years' verifiable experience in the installation and commissioning of aerodrome alerting or equivalent emergency notification systems, and shall furnish references upon request.

3. All equipment shall be new, un-used, and free from defects. Equipment from a single manufacturer shall be preferred for the CACP and all field devices to ensure system-wide compatibility and single-vendor accountability.
4. All equipment shall be CE-marked and/or listed to UL, FM, or equivalent third-party certification body acceptable to the Engineer. Equipment conforming to EN 54-16 (voice alarm) and EN 54-2 (control panels) is preferred.
5. All equipment shall be supported by manufacturer's routine test certificates and, where applicable, type test certificates in accordance with the standards cited in Clause 1.02. Certificates shall be submitted as part of the equipment data package under Clause 1.05 and are mandatory for equipment approval prior to delivery to site.

1.07 DELIVERY, STORAGE AND HANDLING

1. All equipment shall be delivered to site in original manufacturers' packaging with documentation intact. The Contractor shall verify quantities and check for transit damage upon delivery and notify the Engineer immediately of any discrepancies.
2. Equipment shall be stored in a dry, weather-protected, heated (minimum 5°C) storeroom. Battery modules shall not be stored at temperatures below 5°C and shall be maintained on trickle charge from date of delivery.
3. Given the remote location and altitude of Skardu (2,228 m MSL), the Contractor shall account for high-altitude de-rating of electronic equipment and ensure all selected equipment is rated for operation at or above 2,500 m MSL.

1.08 SITE CONDITIONS

1. Skardu International Airport, Gilgit-Baltistan, Pakistan. Latitude approximately 35.3°N, Longitude 75.6°E. Elevation 2,228 m (7,310 ft) MSL.
2. Ambient temperature range: -10°C to +41°C per Electrical Design Report. All equipment shall be rated for this full range without derating below specification.
3. Maximum humidity: 90% RH non-condensing.
4. Seismic Zone 4 per Building Code of Pakistan (BCP 2021). All panel racks, wall-mounted units, and cable tray shall be seismically braced and anchored per BCP seismic provisions.
5. Snow loading is significant in winter months. All outdoor-mounted or roof-mounted components shall be designed for a snow load of not less than 2.0 kPa on any horizontal surface, with drainage details to prevent ice bridging over cable entry points.
6. The site is subject to strong katabatic winds. All external enclosures shall be mechanically fastened and gasketed for wind-driven rain resistance equivalent to IP 65.

1.09 WARRANTY

1. The Contractor shall provide a written warranty, from the equipment manufacturer, covering defects in materials and workmanship for a minimum period of twenty-four (24) months from the date of the Completion Certificate issued by the Engineer.

2. During the warranty period, the Contractor shall respond to any system fault or failure within forty-eight (48) hours and restore full system operability within seventy-two (72) hours. ARFF response capability shall be maintained at all times during any maintenance or repair.
3. A list of recommended spare parts for two (2) years' operation, with unit prices, shall be submitted with the O&M manual.

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Equipment Schedule

The minimum equipment to be supplied, installed, and commissioned under this Section is tabulated below. Quantities are indicative; the Contractor shall verify quantities from coordinated architectural and electrical drawings.

Tag	Equipment Item	Location	Quantity
CACP-01	Crash Alarm Control Panel	ARFF Fire Station – Equipment Room	1 No.
CAP-01	Crash Alarm Push Button (ATC)	ATC Tower – Watch Supervisor Console	1 No.
CAP-02	Crash Alarm Push Button (Remote)	Crash Gate No. 1	1 No.
CAP-03	Crash Alarm Push Button (Remote)	Crash Gate No. 2 (if provided)	1 No.
HO-01	Electronic Hooter / Siren (110 dB)	ARFF Station – Appliance Bay (East)	1 No.
HO-02	Electronic Hooter / Siren (110 dB)	ARFF Station – Appliance Bay (West)	1 No.
CB-01	Crash Bell (200mm gong)	ARFF Station – Watch Room	1 No.
CB-02	Crash Bell (200mm gong)	ARFF Station – Rest Room / Dormitory	1 No.
STR-01	Visual Strobe Beacon (Amber)	ARFF Station – External Facade	2 No.
STR-02	Visual Strobe Beacon (Amber)	Appliance Bay Interior, each bay	2 No.
TP-01	Crash Telephone (Direct Line)	ATC Tower – Watch Supervisor Console	1 No.
TP-02	Crash Telephone (Direct Line)	ARFF Station – Watch Room	1 No.
PSU-01	Dedicated Power Supply Unit + 24hr Battery Backup	ARFF Station – Equipment Room	1 No.
ANN-01	Annunciator / Repeater Panel	ATC Tower Base / Entry Lobby	1 No.

B. Performance Envelope

All system components shall comply with the following performance parameters as a minimum:

Parameter	Requirement
Operating Temperature	–10°C to +41°C (Site ambient per Electrical Design Report)
Altitude	≥ 2,228 m MSL – equipment rated for high-altitude operation; de-rating applied where required
Humidity (max.)	90% RH non-condensing
Seismic	Seismic Zone 4 per BCP 2021; all racking and mounting to resist 0.3g horizontal acceleration
Audible Level – Hooter/Siren	Minimum 110 dB(A) at 1 m; minimum 15 dB(A) above ambient in all occupied ARFF spaces
Audible Level – Crash Bell	Minimum 90 dB(A) at 1 m
Visual Beacon Flash Rate	60–120 flashes per minute per NFPA 72
Panel Response Time	Alarm activation to all outputs within 3 seconds of pushbutton operation
Backup Power Duration	Minimum 24 hours standby followed by 30-minute alarm condition per NFPA 72
Cable Insulation Rating	Minimum 450/750 V; fire-rated (LSZH) for all alarm circuits
Enclosure – External devices	Minimum IP 65 per IEC 60529
Enclosure – Indoor panel	Minimum IP 41 per IEC 60529; dust and vermin proof
MTBF (minimum)	50,000 hours for control panel and all field devices
Warranty	Minimum 24 months from date of Completion Certificate

2.02 CRASH ALARM CONTROL PANEL (CACP)

A. General

The CACP shall be the central intelligence and power distribution unit of the System. It shall be a microprocessor-based unit specifically designed for aerodrome crash-alarm or equivalent industrial emergency alerting applications.

B. Enclosure

1. Wall-mounted, sheet steel, minimum 1.5 mm thick, powder-coated RAL 7035 light grey.
2. Hinged lockable door with internal illumination.
3. Minimum IP 41 per IEC 60529, dust-proof and vermin-proof.
4. Equipped with perforated bottom cable entry plate with removable blanking plugs.
5. Minimum internal dimensions: 600 mm (H) × 500 mm (W) × 200 mm (D). Final dimensions to accommodate all internal components with 30% spare space.

C. Control and Indication

The CACP front panel shall provide as a minimum:

1. Alarm-level selector pushbuttons (one per level) with illuminated surround and mechanical guards to prevent accidental activation.
2. Individual LED status indicators per field circuit (green = healthy, amber = fault, red = active alarm), minimum 5 mm diameter LEDs.
3. POWER ON indicator (green).
4. MAINS FAIL indicator (amber) with battery voltage digital display.
5. SYSTEM FAULT indicator (amber) with audible buzzer and silence pushbutton.
6. ALARM ACTIVE indicator (red, flashing) with manual reset pushbutton (key-switch protected).
7. ALL CLEAR / CANCEL pushbutton (key-switch protected) to silence all outputs and reset the system.
8. LCD alphanumeric display, minimum 4 lines × 40 characters, backlit, displaying real-time event status and event log.
9. USB port and/or Ethernet port for event-log download and remote monitoring.

D. Processing and Logic

1. The CACP shall incorporate dual redundant microprocessors (active-standby configuration) so that failure of any single processor does not impair system functionality.
2. All alarm logic (input prioritisation, output sequencing, zone mapping) shall be field-configurable via password-protected software accessible through the front panel LCD and keypad or via a laptop connected to the service port. No proprietary programmer shall be required for routine reprogramming.
3. The CACP shall maintain a non-volatile event log with a minimum capacity of 5,000 events, each entry recording: date, time (to 1-second resolution), event type, device identity, and operator ID (if applicable). The log shall be downloadable to standard CSV format.

E. Input / Output Capacity

1. Minimum supervised input circuits: 8 addressable or zoned, expandable to 16.
2. Minimum supervised output circuits: 8, each rated minimum 2 A at 24 V DC, expandable to 16.
3. Dry-contact (volt-free) relay outputs: minimum 4, rated 5 A / 250 V AC, for BMS integration and remote annunciator.
4. All input and output circuits shall be end-of-line (EOL) resistor-supervised for open and short circuit, with each fault condition individually annunciated.

2.03 ALARM INITIATION DEVICES – CRASH ALARM PUSH-BUTTON STATIONS

1. Push-button stations shall be specifically manufactured for aerodrome crash-alarm applications. Each station shall comprise:
 - a. Stainless steel or ABS front plate, flush or surface mounting.

- b. Minimum one (1) illuminated pushbutton per alert level, RED in colour, 40 mm minimum diameter, recessed 3 mm behind flush guard to prevent accidental activation.
 - c. Key-switch (RESET / CANCEL) for authorised cancellation of alarm.
 - d. Integral alarm-level selector (or selector at CACP with remote push-button activation).
 - e. Separate acknowledgement (ACK) button.
 - f. Weatherproof to IP 54 minimum for crash-gate stations; IP 41 for indoor ATC console stations.
2. The push-button at the ATC Watch Supervisor Console shall be integrated into the console furniture with a lockable clear polycarbonate hinged cover engraved 'CRASH ALARM – LIFT COVER TO OPERATE'.
 3. Remote crash-gate push-button stations shall be housed in a bright-red powder-coated steel enclosure, mounted at 1,400 mm above finished floor level, with 100 mm high retroreflective label reading 'CRASH ALARM'.

2.04 AUDIBLE ALARM DEVICES

A. Electronic Hooters / Sirens

Electronic hooters/sirens shall be self-contained units designed for high-ambient-noise industrial or aerodrome environments. Technical requirements:

1. Output: minimum 110 dB(A) at 1 m, measured in a free field at the rated supply voltage.
2. Tone patterns: minimum 10 programmable tone patterns including continuous, pulsed, warble (Hi-Lo), and swept-frequency whoop.
3. Frequency range: 400 Hz to 3,200 Hz (primary fundamental), selectable.
4. Supply voltage: 24 V DC from the CACP, supervised circuit.
5. Current draw: not exceeding 500 mA at rated output.
6. Enclosure: minimum IP 65 per IEC 60529; UV-stabilised ABS or die-cast aluminium; operating range -20°C to +55°C.
7. Mounting: wall/ceiling bracket with 360° horizontal adjustment; cable entry from rear or base with IP-rated gland.
8. Colour: red or orange RAL 2009, as approved by the Engineer.
9. Certification: CE-marked; FM or UL listed; or equivalent to EN 54-3 (Fire Alarm Sounders).

B. Electromechanical Crash Bells

Crash bells shall be motorised gong-type electric bells suitable for aerodrome and fire-station applications. Technical requirements:

1. Gong diameter: minimum 200 mm (8 inches) chrome-plated steel.
2. Striking mechanism: self-interrupting solenoid or motor-driven, continuous operation rated.
3. Sound output: minimum 90 dB(A) at 1 m.
4. Supply voltage: 24 V DC, supervised circuit from CACP.

5. Enclosure: weather-resistant die-cast aluminium or brass housing; minimum IP 54.
6. Colour: bright red or fire-engine red; gong and hammer exposed for visual confirmation of operation.
7. Mounting: wall or ceiling bracket with screwed conduit entry; vibration-absorbing pad between bell body and mounting surface.
8. Conformance: manufactured and tested in accordance with BS 5839 Part 1 or equivalent.

2.05 VISUAL ALARM DEVICES – STROBOSCOPIC BEACONS

Visual alarm beacons shall supplement audible devices in high-noise environments (appliance bays) and provide visual alerting where hearing protection is worn. Requirements:

1. Light source: high-intensity Xenon strobe or LED array.
2. Colour: Amber (yellow) per NFPA 72 Table 18.5.5.5 for non-fire emergency visual signals; must be distinctly different from red fire alarm strobes. [NOTE: Confirm colour coding with PAA/ATC authority prior to procurement]
3. Flash rate: 60 to 120 flashes per minute per NFPA 72.
4. Luminous intensity: minimum 15 candela (cd) in all directions of the protected space; calculation to demonstrate compliance with NFPA 72 photometric requirements.
5. Supply voltage: 24 V DC, supervised circuit from CACP.
6. Enclosure: minimum IP 65 for external-facade units; minimum IP 41 for indoor units.
7. Mounting: surface or conduit-entry box; 360° lens for corridor/appliance bay wide-angle coverage preferred.
8. Certification: CE-marked; listed to EN 54-23 (Visual Alarm Devices) or UL 1971.

2.06 DIRECT-LINE CRASH TELEPHONE (HOTLINE)

1. The crash telephone system shall provide a dedicated, always-available, no-dial voice circuit between the ATC Watch Supervisor position and the ARFF Watch Room, conforming to FAA AC 150/5210-7D requirements for aerodrome emergency communications.
2. The crash telephone shall be:
 - a. A two-wire dedicated private line (not routed through the PABX or public exchange) – separate physical pair.
 - b. Designed so that lifting either handset automatically establishes the connection and rings the opposite instrument.
 - c. Equipped with a loud ringing alert (minimum 85 dB(A) at 1 m) and a flashing visual indicator (red LED ring around handset base).
 - d. Provided with a backup internal battery capable of maintaining the telephone circuit operational for a minimum of 4 hours on loss of mains power, in addition to the CACP backup battery.
 - e. Housed in a distinctive red handset cradle/case labelled 'CRASH PHONE – DO NOT USE FOR ROUTINE CALLS' in both English and Urdu.
 - f. Wall-mounted at 1,200 mm AFFL, within 600 mm of the Watch Supervisor chair position at the ATC console.

3. Cable: Dedicated 2-core LSZH telephone cable (minimum 0.5 mm² conductors, 300 V rated) installed in separate conduit from all other systems.

2.07 POWER SUPPLY AND BATTERY BACKUP

1. The CACP shall incorporate a dedicated regulated dual-source power supply unit (PSU) comprising:
 - a. Mains Input: 230 V AC $\pm 10\%$, 50 Hz single phase, from a dedicated ARFF station circuit breaker on the distribution board.
 - b. DC Output: 24 V DC $\pm 5\%$ regulated, ripple < 100 mV rms.
 - c. Output Current: Sufficient to power all connected field devices at rated output simultaneously, plus 25% spare capacity.
 - d. Battery Charger: Intelligent float/equalise charger with automatic boost charge after discharge, temperature-compensated.
2. Standby Battery:
 - a. Sealed valve-regulated lead-acid (VRLA) or equivalent maintenance-free technology.
 - b. Capacity: Sized to maintain the System in STANDBY mode for a minimum of 24 hours, followed by a minimum of 30 minutes in full ALARM condition, per NFPA 72 Chapter 10.
 - c. Battery sizing calculation shall be submitted with the system design documentation as required under Clause 1.05.
 - d. Battery ambient temperature at the installation location: 5°C to 35°C; de-rating applied for temperatures outside the 20°C nominal range per manufacturer's data.
 - e. Battery shall be housed within the CACP enclosure or in an adjacent battery cabinet on the same wall with inter-connecting LSZH cable.
3. An automatic voltage-regulator / surge-protection device (SPD) shall be installed at the mains input to the CACP, rated for Category III per IEC 61643-11, to protect against voltage surges and lightning-induced transients.
4. Loss of mains power shall be indicated immediately on the CACP front panel and transmitted to the BMS via volt-free contact without activating the alarm.

2.08 WIRING AND CABLES

1. All wiring shall comply with the general requirements of Section 0610 – Conduits and Pipes and Section 0590 – Low Tension Cables of this Volume, with the additional requirements below.
2. Field device circuits (alarm output and initiation input loops) shall use:
 - a. LSZH-sheathed multi-core twisted pair cable, minimum 1.5 mm² stranded copper conductors, rated 300/500 V, with overall screen (drain wire, foil).
 - b. Cable to be fire-resistant in accordance with IEC 60331-2, maintaining circuit integrity for minimum 60 minutes at 750°C (equivalent to BS 7629 or EN 50200 Category PH 60).
3. Crash telephone circuit cable: dedicated 2-core LSZH, 0.5 mm² minimum, 300 V, as specified in Clause 2.06.3.
4. All field device circuit cables shall be enclosed in dedicated steel or HDPE conduits. Crash alarm cables shall not share conduit with power circuits (230 V or 415 V), fire alarm cables, or IT/data cables.
5. Minimum conduit size: 20 mm diameter; no conduit shall carry more circuits than permitted by IEE Wiring Regulations (50% fill rule for multi-core cables in dedicated conduits).

6. All cables shall be labelled at both ends and at every junction box with a durable cable tag bearing circuit designation per the cable schedule. Cable tags shall be of the clip-on or tie-on type, heat-stamped or engraved; hand-written tags are not acceptable.

2.09 CONDUITS, JUNCTION BOXES, AND ENCLOSURES

1. Conduit shall comply with Section 0610 – Conduits and Pipes of this Volume. For the crash alarm system, rigid steel conduit (RSC) shall be used in all exposed or vulnerable locations (appliance bays, external, underground). HDPE heavy-duty conduit may be used underground with prior Engineer approval.
2. Junction boxes shall be:
 - a. 16 SWG sheet steel (internal), hinged and gasketed for IP 54 minimum. External junction boxes: die-cast aluminium or GRP, IP 65 minimum.
 - b. Labelled on the cover with engraved label: 'CRASH ALARM – AUTHORISED ACCESS ONLY'.
 - c. Each box shall contain an EOL resistor in a labelled resistor holder as applicable.
3. All entry points for conduit, cables, and wiring to the CACP and field devices shall use IP-rated brass cable glands with PVC shroud, sized to maintain the enclosure IP rating.

2.10 EARTHING AND BONDING

1. The crash alarm system shall comply with Section 0620 – Earthing / Grounding System of this Volume. Additionally:
 - a. The CACP chassis and all metallic field device enclosures shall be bonded to the building earth system via a dedicated 4 mm² green/yellow PVC-insulated copper earth conductor.
 - b. Cable screens shall be earthed at one end only (CACP end) to avoid earth loops; the field end shall be left insulated, sleeved, and identified.
 - c. The crash telephone dedicated pair cable screen shall be earthed at the ATC Tower end only.
 - d. Earth resistance from any bonded component to the nearest earth electrode shall not exceed 1 Ω , per Section 0620 testing requirements.

2.11 SPARE PARTS

The following minimum spare parts shall be supplied with the System and handed over to the Owner at the time of acceptance:

1. Fuses: 100% of each type and rating used in the System.
2. EOL resistors: 200% of each value used.
3. Indicator LEDs: 200% of each type used on the CACP front panel.
4. Complete replacement hooter/siren: 1 No.
5. Complete replacement crash bell: 1 No.
6. CACP processor/controller board: 1 No. (or equivalent module per manufacturer's recommendation).

PART 3 – EXECUTION

3.01 EXAMINATION

1. The Contractor shall inspect all areas where the System is to be installed prior to commencement. Any condition detrimental to the installation – including uncompleted civil or structural works, inadequate access, or interference from other services – shall be reported to the Engineer in writing before work commences.
2. Commencement of installation shall constitute the Contractor's acceptance that existing conditions are satisfactory.

3.02 INSTALLATION

A. General

1. Installation shall be carried out by competent, licensed electricians supervised by a qualified engineer. The Contractor shall keep pace with the Civil Contractor's programme and shall coordinate all conduit embedment prior to concrete pours as specified in Section 0610 – Conduits and Pipes of this Volume.
2. Installation shall conform to the approved shop drawings, relevant IEE Wiring Regulations, the Pakistan Electricity Act/Rules, and the requirements of ICAO Doc 9137 Part 1.

B. Crash Alarm Control Panel

1. The CACP shall be mounted in the ARFF Station Equipment Room at a height with the centre of the display at approximately 1,500 mm AFFL. The wall construction shall be verified to support the panel weight plus battery cabinet; additional blocking or steel framing shall be provided if required.
2. A minimum 300 mm clear service space shall be maintained around all sides of the CACP and battery cabinet.
3. The CACP shall be earthed as described in Clause 2.10.

C. Field Devices

1. Hooters and crash bells shall be mounted at a minimum height of 2,400 mm AFFL in appliance bays and at 2,100 mm AFFL in the watch room and dormitory, positioned for maximum acoustic coverage and unobstructed sound propagation.
2. Strobe beacons in appliance bays shall be located so that the light source is visible from anywhere within the bay; multiple units shall be installed if single-unit coverage is insufficient per NFPA 72 photometric tables. Beacons shall not be aimed directly at vehicle operators' eye level.
3. External strobe beacons on the ARFF station facade shall be mounted at a height of minimum 3,000 mm above external finished ground level and shall be aimed to be visible from the crash-gate approach roads.
4. Push-button stations shall be accessible without obstruction at all times. Crash-gate stations shall be mounted on a separate post or on the gate control column, not on the gate itself.

D. Cables and Conduits

1. All cable installation shall comply with Section 0590 – Low Tension Cables of this Volume, with the additional LSZH and fire-resistance requirements of Clause 2.08.

2. Where crash alarm cables pass through walls or floor slabs, fire-rated duct sealant (intumescent type, minimum 2 hours' fire resistance) shall be applied around every cable penetration.
3. A minimum separation of 150 mm shall be maintained between crash alarm conduits and power conduits (230 V/415 V circuits). Where they must cross, crossing shall be at 90° with 50 mm clear separation.

3.03 FIELD QUALITY CONTROL

A. Pre-Commissioning Checks

Prior to energisation, the Contractor shall carry out the following checks and record results:

1. Visual inspection of all conduit, cable, junction boxes, and field devices for correct installation per approved drawings.
2. Continuity test of every circuit conductor from CACP terminal to field device terminal.
3. Insulation resistance test on every circuit at 500 V DC; minimum acceptable reading: 5 M Ω per Section 0490 – General Requirements for Electrical Works of this Volume.
4. Earth continuity test: $\leq 1 \Omega$ from every bonded enclosure to main earth point per Clause 2.10.
5. Polarity check of all DC circuits.
6. Battery: Verify correct seating, terminal connection, and initial capacity by discharge test at rated load.

B. Functional Testing

After energisation and CACP programming, the Contractor shall conduct a comprehensive functional test in the presence of the Engineer, verifying each of the following:

1. Each initiation push-button activates the correct alarm level at the CACP within 3 seconds.
2. All hooters, sirens, crash bells, and strobe beacons activate simultaneously for every alarm level.
3. Correct tone patterns and alarm-level differentiation for each alert level.
4. CACP front-panel indicators, LCD display, and event log record each event correctly with accurate date and time.
5. Remote annunciator panel reflects all status changes.
6. Circuit fault simulation: each field-circuit EOL resistor removed in turn; CACP annunciates correct fault without initiating alarm.
7. Short-circuit simulation: each field circuit shorted in turn; CACP annunciates correct fault.
8. Mains power removed: CACP transfers seamlessly to battery; no alarm activation; MAINS FAIL indicator illuminates.
9. Battery capacity verification: system maintained under simulated standby load for 24 hours, followed by 30-minute full alarm load; voltage remains above CACP minimum operating voltage throughout.

10. ALL CLEAR / CANCEL function: all outputs extinguish; reset requires key-switch operation.
11. BMS dry-contact output verified to operate correctly at the BMS panel.
12. Crash telephone: both ATC and ARFF handsets tested for call initiation, audibility (speech quality), and visual ring indicator operation.
13. Acoustic measurement: sound level meter readings taken at representative positions in each protected space; minimum 15 dB above measured ambient documented.

3.04 COMMISSIONING AND ACCEPTANCE

1. Commissioning shall not commence without the Engineer's written approval of all pre-commissioning check results and all required submittals listed in Clause 1.05.
2. All functional test results shall be recorded on a test sheet signed by both the Contractor's commissioning engineer and the Engineer's representative. Three (3) copies of all test records shall be submitted to the Engineer within seven (7) days of test completion.
3. The Contractor shall demonstrate that each alarm level produces the correct response in an integrated manner with the ARFF crew at the ARFF Station. A live drill simulating a full emergency (FULL EMERGENCY level) shall be conducted at the request of the Engineer, with PAA ARFF management present.
4. The System shall not be accepted until all functional tests have been completed successfully. Any item failing to meet specification shall be rectified and re-tested at the Contractor's cost.

3.05 TRAINING

1. Prior to or concurrent with system acceptance, the Contractor shall provide formal training to the Employers' designated ARFF and ATC staff. Training shall cover:
 - a. System overview, design intent, and alarm level philosophy per ICAO Doc 9137 Part 1.
 - b. Operation of the CACP: alarm initiation, escalation, cancellation, and reset procedures.
 - c. Daily self-test procedure.
 - d. Fault indication recognition and basic fault investigation.
 - e. Battery maintenance checks and replacement procedure.
 - f. Use of the crash telephone hotline.
 - g. Event log download and review.
2. Training sessions shall be a minimum of four (4) hours duration. The Contractor shall provide printed training materials in English. A training attendance register shall be signed by all trainees and submitted to the Engineer.

3.06 AS-BUILT DOCUMENTATION

1. The Contractor shall maintain accurate as-built records throughout installation, recording all deviations from the approved shop drawings. As-built drawings shall be submitted for Engineer's approval before the final payment certificate is issued.
2. As-built drawings shall include: system block diagram, riser/schematic diagram, device location plan (on coordinated architectural background), cable schedule, conduit routing plan, and CACP wiring diagram showing as-installed circuit connections.
3. Reproducible tracings and digital AutoCAD/DWG files shall be submitted. These drawings become the property of the Owner upon approval.

3.07 PROTECTION

1. The Contractor shall protect all installed System components from damage during subsequent construction activities. Protective covers shall be fitted over field devices until final acceptance. Any component damaged during construction shall be replaced at the Contractor's cost.
2. The crash alarm system shall remain operational (or be immediately restorable to operational status) at all times during the construction and commissioning phases, given that the ARFF facility may be required to support ongoing airport operations at Skardu International Airport.

PART 4 – MEASUREMENT AND PAYMENT

1. For the purpose of measurement and payment, the Airport Crash Alarm and Emergency Alerting System shall be treated as a lump-sum item inclusive of:
 - a. All equipment, materials, labour, transport, and tools.
 - b. All conduit, cable, junction boxes, supports, labels, and earthing.
 - c. CACP programming, commissioning, and functional testing.
 - d. Training, as-built documentation, O&M manuals, and spare parts.
2. Any items not explicitly listed in the Bill of Quantities but necessary for a complete, fully functional, and ICAO-compliant crash alarm system shall be deemed included in the Contractor's lump-sum rate.

SECTION 0920 – GYM AND EXERCISE EQUIPMENT

PART 1 – GENERAL

1.1 SUMMARY

Scope: A.

This Section covers the supply, delivery, installation, testing and commissioning of commercial-grade gym and exercise equipment for the staff recreational gymnasium at Skardu International Airport, Gilgit-Baltistan. The equipment shall include cardiovascular machines, strength training systems, free weights and accessories, functional training equipment, gym flooring, mirrors, and fitness assessment devices as itemised in the Bill of Quantities (BOQ Section 2, Items i through xxviii).

Related Sections: B.

- Section 0010 – Submittal Procedures
- Section 0010 – Closeout Submittals
- Section 0150 – Resilient Sheet Flooring (for subfloor preparation)
- Section 0490 – Low-Voltage Electrical Distribution (for powered equipment circuits)
- Section 0010 – Site Office Facilities (for facility context)

1.2 REFERENCES AND APPLICABLE STANDARDS

All equipment shall comply with the latest editions of the following standards, as applicable to each equipment type:

STANDARD / CODE	TITLE / APPLICATION
ASTM F1250	Standard Specification for Motor-Driven Treadmill
ASTM F2115	Standard Specification for Stationary Bikes
ASTM F1749	Standard Terminology for Exercise Equipment
EN ISO 20957-1	Stationary Training Equipment — General Safety Requirements and Test Methods
EN ISO 20957-2	Strength Training Equipment — Safety Requirements and Test Methods
EN ISO 20957-5	Stationary Cycling Machines — Additional Safety Requirements
EN ISO 20957-6	Treadmills — Additional Safety Requirements
EN ISO 20957-7	Rowing Machines — Additional Safety Requirements
EN ISO 20957-10	Exercise Bikes with Fixed Wheels — Additional Safety Requirements
UL 1816 / IEC 60335	Safety of Household and Similar Electrical Appliances (motorised equipment)
CPSC 16 CFR Part 1207	Consumer Product Safety Standards for Exercise Equipment
BS EN 1177	Impact Attenuating Playground Surfacing — Determination of Critical Fall Height
ASTM F1292	Standard Specification for Impact Attenuation of Surfacing Materials within the Use Zone

Pakistan Electricity Rules 1937	For all electrically powered equipment connections
NEPRA Standards	For electrical installations within Pakistan

1.3 SUBMITTALS

The Contractor shall submit the following in accordance with Section 0010:

- A. Product Data: Manufacturer's technical data sheets for each item of equipment, including dimensions, weight, electrical requirements (voltage, amperage, circuit type), structural loading, material specifications and finish options. Submit minimum 4 weeks before delivery.
- B. Shop Drawings: Floor plan layout showing equipment placement, clearances, anchor locations, cable/power chase routing, and mirror mounting details. Drawn to minimum 1:50 scale.
- C. Certificates: Copies of applicable EN ISO 20957, CE, UL, or ASTM certification for each equipment item from an accredited third-party testing laboratory. Equipment without valid certification shall not be accepted.
- D. Samples: Colour/finish samples for frame powder-coat, upholstery, gym flooring, and mirror frame (where applicable) for Engineer's approval before bulk order.
- E. Warranties: Executed manufacturer's warranty documents for each item, per Clause 1.6.
- F. Operation and Maintenance Manuals: Manufacturer's manuals (in English) covering operating procedures, routine maintenance schedules, lubrication requirements, and spare parts list. Submit at Practical Completion.
- G. Training Records: Written confirmation that operator training has been completed per Clause 3.5.

1.4 QUALITY ASSURANCE

Commercial Grade: A.

All equipment shall be of commercial grade, rated for continuous multi-user operation not less than 8 hours per day, 365 days per year. Residential or light-commercial grade equipment is not acceptable.

Manufacturer Qualification: B.

Each item shall be manufactured by a firm with a minimum of 5 years' experience producing commercial fitness equipment. Manufacturer shall have an established after-sales service and spare-parts network in Pakistan.

Installer Qualification: C.

Installation shall be carried out by personnel trained and authorised by the equipment manufacturer or their authorised distributor. Proof of authorisation shall be submitted to the Engineer prior to commencement of installation.

Pre-delivery Inspection: D.

The Engineer reserves the right to inspect equipment at the Contractor's storage facility or at the manufacturer's premises prior to delivery to site.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in manufacturer's original packaging, clearly labelled with item description, model number, serial number, and weight.
- B. Store in a clean, dry, weather-tight enclosure at site at temperatures between 5°C and 40°C. Equipment shall not be exposed to rain, condensation, or direct sunlight during storage.

- C. Handle equipment using appropriate mechanical aids to prevent damage to frames, upholstery, electronic consoles, and finish surfaces. Do not drag equipment across finished floors.
- D. Gym flooring and rubber mats shall be stored flat or on rolls as recommended by manufacturer; do not store under heavy loads.
- E. Deliver mirrors in manufacturer's protective crates; handle with trained mirror-handling personnel. Do not store mirrors without edge protection.

1.6 WARRANTY

The Contractor shall provide manufacturer's written warranties as follows:

ATTRIBUTE	MINIMUM WARRANTY PERIOD
Structural/frame welds — cardiovascular machines	Lifetime of product (or min. 10 years)
Structural/frame welds — strength equipment	Lifetime of product (or min. 10 years)
Mechanical components (belts, bearings, pulleys, cables)	3 years
Electronic components / display consoles	3 years
Upholstery and upholstered pads	2 years
Treadmill drive motor	5 years
Treadmill running belt and deck	3 years
Gym flooring / rubber tiles	5 years
Wall-mounted mirrors (delamination, edge seal)	5 years
Free weights (barbells, dumbbells, plates, kettlebells)	5 years against cracking/deformation
Labour (all items)	1 year from date of Practical Completion

Warranty periods commence from the date of Practical Completion (TOC) of the Works. During the warranty period the Contractor shall replace defective parts and carry out all repairs at no cost to the Employer.

1.7 MAINTENANCE

- A. Submit a 12-month preventive maintenance schedule with the O&M Manuals covering: lubrication intervals, belt tension checks, pad inspection, calibration of monitoring equipment, and electrical safety checks.
- B. Contractor shall carry out a maintenance service visit at 6 months and 12 months after TOC as part of the Contract obligations.

PART 2 – PRODUCTS

2.1 GENERAL REQUIREMENTS FOR ALL EQUIPMENT

- A. All exposed steel frames shall be finished with minimum 2-coat thermosetting powder-coat paint, minimum 60–80 microns total dry film thickness, hardness $\geq$ 2H pencil, cross-hatch adhesion Class 0 per ISO 2409.
- B. All bolted connections shall use stainless steel or zinc-plated hardware. Anti-loosening provisions (nylon-insert nuts, thread-lock adhesive, or split washers) shall be used on all vibration-prone joints.

C. Upholstery for pads, seats and back-rests: minimum 8 lb/ft³ high-density foam with anti-microbial, moisture-resistant vinyl or commercial gym upholstery fabric. Stitching: double-stitched with UV-stable polyester thread.

D. All motorised equipment shall be rated for the local electrical supply: 220–240 V / 50 Hz / single-phase or 380–415 V / 50 Hz / three-phase as stated per item. Equipment shall include built-in surge protection and emergency stop feature.

E. Digital consoles (where specified) shall display: elapsed time, distance, speed/resistance, calories, heart rate input (contact grip and/or wireless), and programme selection.

F. Approved manufacturers include but are not limited to: Sports Art, Vibe Fitness, Life Fitness, Technogym, Precor, Matrix Fitness, Hammer Strength, Cybex, Star Trac, Body-Solid (commercial range), Concept2, StairMaster, or approved equal of equivalent commercial quality. The Contractor shall supply equipment from the confirmed quotation by Sports Art / Vibe (Quotation Ref: 26GE-Ahmad_Ali-Vibe_Quote-03072026) or approved equivalent meeting these specifications.

2.2 CARDIOVASCULAR EQUIPMENT

2.2.1 Commercial Motorized Treadmill [BOQ Item 2-i] — Basis of Design: Sports Art Prime Line T673L

Provide commercial-grade motorised treadmill with the following minimum specifications:

ATTRIBUTE	MINIMUM REQUIREMENT
Motor	4.0 HP continuous-duty AC drive motor; 5.0 HP peak (Sports Art T673L: 4HP AC Motor)
Running Surface	Minimum 560 mm × 1,520 mm (22" × 60") orthopaedic running belt
Speed Range	0.8 – 20 km/h in 0.1 km/h increments
Incline Range	0 – 15% in 0.5% increments; motorized
Max. User Weight	180 kg (400 lbs) minimum
Console	LCD/LED touchscreen; programmes: Manual, Interval, HRC, Custom (≥ 10 programmes)
Heart Rate	Contact grip sensors + wireless telemetry (ANT+/Bluetooth compatible)
Safety	Magnetic safety key tether with auto-stop; emergency stop button
Frame	Commercial-grade steel, powder-coated; foldable only with Engineer approval
Drive System	DC drive with eddy-current braking; low-noise belt system
Electrical	220–240 V / 50 Hz / single-phase; 20 A dedicated circuit
Certification	CE marked; EN ISO 20957-6; ASTM F1250 compliant

2.2.2 Stationary Spin Bike [BOQ Item 2-ii] — Basis of Design: Vibe US-PG1399

ATTRIBUTE	MINIMUM REQUIREMENT
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Flywheel	Minimum 18 kg (40 lb) chrome-balanced flywheel; perimeter-weighted
Resistance	Magnetic resistance; minimum 32 levels; micro-adjustable
Drive	Belt drive (poly-V); maintenance-free; bidirectional
Pedals	Dual-sided: SPD clip-in + standard cage; Q-factor ≤ 155 mm
Saddle	4-way adjustable (fore/aft + height); quick-release; padded gel saddle
Handlebar	Multi-position; 2-way adjustable (height); clip-on aero bars acceptable
Max. User Weight	150 kg (330 lbs) minimum
Frame	Welded steel; powder-coated; oversized base frame for stability
Console	Backlit LCD: RPM, power (watts), speed, distance, time, calories, HR
Certification	CE marked; EN ISO 20957-10

2.2.4 Rowing Machine – Commercial Grade [BOQ Item 2-iv] — Basis of Design: Vibe Air Rowing Machine VY-YR 400

ATTRIBUTE	MINIMUM REQUIREMENT
Resistance Type	Air resistance; adjustable damper setting (Vibe VY-YR 400: fan-based air resistance)
Frame	Anodized aluminium or powder-coated steel rail; foldable optional
Seat	Contoured, high-density moulded seat; sealed cartridge bearings on slides
Handle	Ergonomic D-handle or straight handle; bungee cord return
Footrests	Adjustable with heel-cup and Velcro strap; pivoting footrests
Monitor	Backlit PM5 equivalent: stroke rate, pace, watts, calories, time, distance
Connectivity	Bluetooth / ANT+ compatible with fitness apps
Max. User Weight	180 kg minimum; usable inseam: 140 cm minimum
Certification	CE; EN ISO 20957-7; Concept2 PM5 monitor or equivalent

2.3 STRENGTH TRAINING EQUIPMENT Note: Additional selectorized strength machines from quotation (Chest Press VY-61A 04, Shoulder Press VY-61A 01, Lat Pulldown VY-61A 15, Leg Extension VY-61A 24, Arm Curl Bench VY-61A 37, Three Station Multi-Gym USBH-143) shall comply with Section 2.3 general requirements and manufacturer's published specifications.

2.3.3 Functional Trainer / Cable Crossover Machine [BOQ Item 2-ix] — Basis of Design: Vibe Cable Cross-Over VY-61A 32

ATTRIBUTE	MINIMUM REQUIREMENT
-----------	---------------------

Weight Stacks	Dual independent stacks; minimum 90 kg (200 lbs) each
Cable Ratio	1:1 direct-pull or 2:1 ratio; clearly labelled
Pulley Travel	Full-height adjustable pulley (floor to ceiling rail); minimum 20 positions
Cables	Aircraft-grade stainless steel cables; minimum 900 kg tensile strength
Attachment Points	Dual rotating swivel D-ring carabiners on each side
Accessories	Minimum 8 attachments: straight bar, rope, D-handle ×4, ankle cuff ×2, lat bar
Frame	11-gauge steel; floor-bolt base; powder-coated
Footprint	Maximum 1,600 mm × 1,000 mm; height ≤ 2,400 mm
Certification	CE; EN ISO 20957-2

2.3.4 Multi-Adjustable Weight Bench [BOQ Item 2-x] — Basis of Design: Vibe Multi-Adjustable Bench VY-61A 46B

ATTRIBUTE	MINIMUM REQUIREMENT
Type	Fully adjustable FID (Flat / Incline / Decline)
Back Pad Positions	Minimum 7 positions: decline –10°, flat 0°, incline 30°/45°/60°/75°/85°
Seat Pad Positions	Minimum 4 positions to prevent sliding
Frame	11-gauge steel; rated ≥ 360 kg total load (user + weights)
Upholstery	High-density foam ≥ 8 lb; commercial vinyl; 75 mm pad thickness minimum
Width	Minimum 290 mm pad width for stability
Wheels	Integrated transport wheels; no permanent anchor required
Certification	CE; EN ISO 20957-2

2.3.5 Flat Weight Bench [BOQ Item 2-xi] — Basis of Design: Vibe Flat Bench VY-61A 47

ATTRIBUTE	MINIMUM REQUIREMENT
Type	Commercial utility flat bench; no adjustment
Frame	11-gauge minimum steel; rated ≥ 360 kg; 4-leg or I-beam design
Upholstery	High-density foam ≥ 8 lb; commercial vinyl; 65 mm pad thickness
Pad Width	Minimum 290 mm
Pad Length	Minimum 1,070 mm (42")
Certification	CE; EN ISO 20957-2

FREE WEIGHTS AND STORAGE

2.4.1 Straight Barbell Set [BOQ Item 2-xii] — Basis of Design: Vibe Straight Round Barbells VN-US1301

ATTRIBUTE	MINIMUM REQUIREMENT
Bar Length	2,200 mm (86") standard Olympic length
Bar Diameter	28–29 mm shaft; 50 mm sleeve (Olympic standard)
Bar Weight	20 kg (men's standard)
Tensile Strength	Minimum 190,000 PSI (1,310 MPa) steel
Knurling	Medium knurling; dual knurl marks (power + Olympic)
Sleeves	Rotating sleeves; needle or bushing bearings; chrome or hard-chrome finish
Collar Snap	Minimum 2 pairs spring collars; quick-release
Certification	IPF or IWF specification compliant; CE

2.4.3 Dumbbell Set [BOQ Item 2-xiv] — Basis of Design: Vibe 12 Edge Premium CPU Dumbbells VN-US1007

ATTRIBUTE	MINIMUM REQUIREMENT
Type	12-Edge (dodecagonal) cast iron CPU dumbbells; anti-roll head; rubber end-cap protection
Range	Complete set as per BOQ quantity; 12-sided (dodecagon) anti-roll head design; Vibe 12 Edge Premium CPU pattern (VN-US1007)
Head Material	Solid cast iron; fully rubber encased; virgin rubber minimum 5 mm thick
Handle	Contoured ergonomic chrome or knurled steel; 30–35 mm diameter
Weight Tolerance	±2% of stated weight
Colour Coding	Weight increments colour-coded or weight-stamped on end-cap
Certification	CE; EN ISO 20957-2

2.4.4 Dumbbell Storage Rack [BOQ Item 2-xv] — Basis of Design: Vibe Series 3 Tier Dumbbell Rack US2017

ATTRIBUTE	MINIMUM REQUIREMENT
Type	3-tier inclined A-frame saddle rack (Vibe Series 3 Tier Dumbbell Rack US2017)
Capacity	Minimum 15 pairs (5 per tier) covering full dumbbell set
Tier Angle	Inclined saddle angled $\geq 15^\circ$ for easy grab
Frame	11-gauge square steel tube; welded construction; powder-coated

Load Rating	Static load rating $\geq$ 1,000 kg total
Rubber Liner	Rubber-lined or UHMW-PE lined saddles to protect dumbbell finish

2.4.5 Barbell / Weight Plate Storage Rack [BOQ Item 2-xvi] — Basis of Design: Vibe Barbell Rack US2031

ATTRIBUTE	MINIMUM REQUIREMENT
Type	Vertical A-frame or Christmas-tree; minimum 10 pegs
Peg Diameter	50 mm (Olympic) to accept all weight plates in set
Peg Length	Minimum 400 mm per peg
Frame	Welded steel; powder-coated; stable base; non-tip design
Load Rating	Minimum 300 kg total

PART 3 – EXECUTION

3.1 EXAMINATION

- A. Before commencing installation, verify that the gym room is fully enclosed, weathertight, all wet trades complete, final floor screed laid and cured, mechanical and electrical services roughed-in and tested, and adequate ventilation/HVAC operational.
- B. Verify room dimensions against approved equipment layout drawings. Report discrepancies of more than 50 mm to the Engineer before proceeding.
- C. Inspect subfloor for levelness: maximum deviation 3 mm under a 3 m straightedge. Notify Engineer of any deviation exceeding this tolerance.
- D. Verify electrical circuit provisions: dedicated circuits with correct amperage, voltage, and earthing for each motorised equipment item.

3.2 INSTALLATION

3.2.1 General

- A. Install all equipment strictly in accordance with the manufacturer's installation instructions and the approved equipment layout drawing.
- B. Maintain minimum clearances: 900 mm around all equipment sides and rear; 1,500 mm at access/egress ends of treadmills and steppers; as per manufacturer recommendation where greater than above.
- C. All equipment requiring floor anchoring shall be anchored using the manufacturer's specified anchor kit. Anchor bolt type, size and embedment depth shall be confirmed against the structural slab design. Do not core-drill without written consent.
- D. Level all equipment using adjustable levelling feet where provided. Maximum out-of-level: 2 mm in any 600 mm run.

3.2.2 Cardio Equipment

- A. Connect motorised equipment to dedicated electrical circuits via NEMA 5-20 or IEC 60309 receptacles as appropriate. Do not share circuits between units.
- B. Install treadmills with safety key attached and magnetic clip verified functional before powering on.

C. Run all power cords through provided cord management channels or surface conduit; no trailing cables across floor.

3.2.3 Strength Equipment and Free Weights

A. Install power rack and smith machine with all J-hooks, safety bars and pull-up attachments before handover.

B. Arrange dumbbells and kettlebells on storage racks in ascending weight order from left to right when facing the rack.

C. Plate storage trees shall be loaded symmetrically to prevent tipping.

3.2.4 Gym Flooring

A. Install flooring after all wall finishes, painting, mirror installation and mechanical/electrical work is complete.

B. Dry-lay interlocking tiles on clean, dry, level subfloor. Begin from a central datum line and work outward to minimise cut pieces at perimeter.

C. Cut tiles using a utility knife and straight edge, or power saw with fine-tooth blade. All cut edges at room perimeter shall be concealed under skirting or bevelled edge strip.

D. At perimeter and under fixed equipment bases, apply double-sided flooring tape or adhesive per manufacturer's specification to prevent tile migration.

3.2.5 Mirrors

A. Install mirrors after gym flooring is laid but before equipment is placed.

B. Apply mirror adhesive to back face in 300 mm vertical ribbons at 400 mm centres. Allow adhesive to form skin before placing mirror.

C. Support each mirror panel with J-channel bottom support rail installed level at 300 mm above finished floor; use spirit level.

D. Apply minimum 2 security mirror clips per panel at top edge.

E. Ensure minimum 25 mm ventilation gap at top and bottom of mirror wall.

F. Seal all vertical joints between mirror panels with clear neutral-cure silicone sealant; maximum 2 mm joint width. Tooled flush.

3.3 FIELD QUALITY CONTROL — TESTING AND COMMISSIONING

A. Cardio Equipment: Run each motorised unit through full speed and incline range. Verify emergency stop, safety key, display functions, all programme modes, and heart-rate receiver. Run treadmill at maximum speed for minimum 5 minutes.

B. Strength Equipment: Load test each cable machine and functional trainer to 110% of rated stack weight. Inspect cable routing, pulleys and attachments.

C. Power Rack and Smith Machine: Verify all J-hooks, safeties, and pull-up bars are secure. Test safety catch function by loading barbell into catches.

D. Gym Flooring: Walk entire installed area; check for lifted edges, unlocked tiles, or hollow sounds indicating adhesion failure.

E. Mirrors: Check for plumb (≤ 2 mm per 1 m height), secure fixing, distortion-free reflection, and sealant continuity at joints.

F. Fitness Assessment Equipment: Power on all electronic items; verify calibration of body composition analyser against known reference weights; test connectivity of HR monitors to compatible display units.

G. Document all commissioning tests in a Commissioning Record and submit to Engineer for countersignature at Practical Completion.

3.4 CLEANING

A. Remove all packaging, strapping, cardboard, and polythene wrap from the gym upon completion of installation.

B. Wipe down all equipment frames, upholstery and consoles with manufacturer-approved cleaning solution.

C. Clean gym flooring per manufacturer's instructions; remove installation adhesive residue.

D. Wipe mirrors clean with glass cleaner; remove all adhesive smears and fingerprints.

3.5 OPERATOR TRAINING

A. Before Practical Completion, provide a minimum half-day (4-hour) structured training session for PAA-nominated gym staff, covering: safe operation of all equipment, routine daily/weekly maintenance checks, cleaning protocols, and emergency procedures.

B. Training shall be conducted by a certified fitness equipment technician from the manufacturer or authorised distributor.

C. Provide printed Quick-Reference Cards (laminated A4) for each major equipment item, to be mounted adjacent to the equipment.

D. Provide two copies of all O&M manuals in English, bound and indexed.

ANNEX 1 — CONSOLIDATED DESIGN PARAMETERS

The following table consolidates the project-wide design parameters and shall be read in conjunction with the corresponding tables in Section 0010 §1.02.1, Section 0490 §1.3, Section 0710 §3.3 and Section 0740 §1.3. Where any apparent conflict remains between the individual Section tables and this Annex, the values in this Annex shall govern.

Parameter	Value	Application / Basis
Seismic zone (structural)	BCP Zone-4, $Z = 0.4$	Structural Design Report; BCP 2007
Seismic — non-structural components	ASCE 7-22 Ch. 13, $I_p = 1.5$ (Risk Category IV)	ICAO Annex 14 essential facility
Wind	Per ASCE 7-22 with altitude correction at 2,230 m AMSL	Structural Design Report
Snow load (roof)	50 lbs/ft ² (2.4 kPa)	Structural Design Report
Winter design dry-bulb (99.6 %)	-18 °C	HVAC envelope and plant sizing
Summer design dry-bulb (0.4 %)	+34 °C	HVAC plant sizing
Equipment qualification envelope	-25 °C to +50 °C	Electrical, electronic and CNS equipment
Site elevation	2,230 m AMSL	Site survey
Air-density correction (HVAC, generators)	0.79 × sea-level	Sec 0710 §1.4
Envelope U-value — opaque wall	$\leq 0.30 \text{ W/m}^2\text{K}$	Cold-climate practice
Envelope U-value — roof	$\leq 0.20 \text{ W/m}^2\text{K}$	Cold-climate practice
Envelope U-value — glazing	$\leq 1.3 \text{ W/m}^2\text{K}$ (low-e, argon, warm-edge)	Cold-climate practice
Glazing SHGC — ATC cabin	0.40–0.55 (orientation tuned)	ICAO Doc 9426
Glazing VLT — ATC cabin	≥ 0.50	ICAO Doc 9426
Envelope air leakage	$\leq 1.5 \text{ m}^3/(\text{h}\cdot\text{m}^2)$ at 50 Pa	ASTM E779 / EN ISO 9972
Building Risk Category	IV (Essential Facility — ATC)	ASCE 7-22 Table 1.5-1
Electricity supply authority	Water and Power Department, Government of Gilgit-Baltistan (GB Power)	Site authority
Indoor — ATC control cabins	22 ± 1 °C; 45–55 % RH	HVAC BOD
Indoor — ATC equipment / server rooms	22 ± 1 °C; 45–55 % RH; continuous	ASHRAE TC 9.9 Allowable

Indoor — offices	23 ± 1 °C; ≤ 60 % RH	HVAC BOD
Indoor — dormitories	22–24 °C; ≤ 60 % RH	HVAC BOD
Indoor — fire truck station	18–20 °C, minimum +13 °C for freeze protection	HVAC BOD

ANNEX 2 — HVAC EQUIPMENT SCHEDULES

Equipment and material shall be supplied only from the approved sources noted below. However, in all cases, the contractor shall submit complete technical details of the equipment, material and obtain consultant's approval prior to purchase/ delivery on site.

Sr.	Description of Equipment / Material	Approved Manufacturer	Country of Origin
1	Chillers	Trane/York/ Carrier / Daikin	USA / EU / Japan (Western) (AHRI/ Eurovent Certified Only)
2	Cooling Tower (Closed Circuit)	BAC / YH / QCR / Baltimore Aircoil Company, GEA Polacel / Kelvin, SPX / Marley, EVAPCO, Kuken or equivalent	China
3	Air Handling Units (AHU's)	Trane/ York/ Untes / Daikin / TROX / Carrier / International Environmental Corporation	USA / EU/ Turkey / Japan (Western) (AHRI/ Eurovent and AMCA Certified Only)
4	Fan Coil Units (FCU's)	Trane/ York/ Untes / Daikin / TROX / International Environmental Corporation	USA / EU / Turkey / Japan (Western) (AHRI/ Eurovent and AMCA Certified Only)
5	Fans		
	Centrifugal/ Propeller/ Axial	Green-Heck/ Pennberry / S&P / Kayi	USA / EU / Turkey (AMCA Certified Only)
	Parking Fan System	Green-Heck/ Pennberry / S&P / Kayi	USA / EU / Turkey (AMCA Certified Only)
6	Support System, Anchors and Concrete Fastner		
	Pipe Support System	Hilti / Fischer / Incofix	USA / EU
7	Ducting & Accessories		
	Sheet Metal	Pakistan Steel/ Approved Equivalent	Pakistan / Imported
	Volume Dampers	Steel Craft / Thermec / EAP / Approved Equivalent	Pakistan
	Fire Dampers	Steel Craft / Thermec / EAP / Approved Equivalent	Pakistan
	Air Devices (Grills, Diffusers and Louvre)	Steel Craft / Thermec / EAP / Approved Equivalent	Pakistan
8	Insulations		
	Duct Insulation	Afico / Kimco /Owens Corning / Incotech	KSA / Kuwait / Turkey
	Canvas Jacket	Approved	Pakistan
	Insulation adhesive	Zahabiya / Duct mate	Pakistan, USA

	Closed Cell Pipe Insulation with Vapor	Aero flex	Thailand
	Adhesive for Pipe Insulation	Zahabiya / Duct mate	Pakistan , USA
	Closed Cell Insulation	Aeroflex	Thailand
9	Piping & Fittings		
	PPRC	Aquatherm	Germany
	Strainers, check valves, butterfly valves, ball valves	SCON	Pakistan
	Refrigerant pipes	Mueller / Golden Dragon	Uk / China
	Tray for refrigerant piping (roof only)	Approved	Pakistan
	G.I. Pipe	IIL	Pakistan
	UPVC	Popular, Beta and Master	Pakistan
	Flexible connectors & pipe Expansion	Approved	Imported
10	Pumps		
	End suction Centrifugal	KSB / Grundfoss/ TACO / WILO	Pakistan , USA, Germany
11	Paints	Berger, ICI, Jotun, Nippon	Pakistan
12	Fire shop	Hilti, Fischer	USA/EU/Japan
13	Motors	Siemens, ABB	USA , Europe, China, Japan
14	Thermometers/ Pressure Guages	Dwyer, Weiss, Terice	USA/EU/Japan
15	Hot Water Generator	Unical/ Bosch / Cleaver Brooks / TICA Climate Solutions	USA/EU/Japan/China
16	Variable Refrigerant Flow (VRF) Units	Toshiba, Mitsubishi, Daikin, Hitachi, Trane, York, LG	China, EU, Korea, Japan, USA

ANNEX 3 — MONTHLY PROGRESS REPORT

PAKISTAN AIRPORTS AUTHORITY

Planning & Development Directorate

MONTHLY PROGRESS REPORT

UPGRADATION OF SKARDU INTERNATIONAL AIRPORT

Report No.	MPR – [Sequential No., e.g., MPR-01]
Period Covered	[DD Month YYYY] to [DD Month YYYY]
Reporting Month	[Month, Year]
PC-I No. / ADP No.	[PC-I Reference Number]
Contract No.	[Contract / Agreement Number]
Contract Commencement	[DD Month YYYY]
Original Completion Date	[DD Month YYYY]
Revised Completion Date	[DD Month YYYY] / Not Applicable
Total Contract Duration	[X] Months (Original) / [X] Months (Revised)
PC-I Approved Cost	PKR [Amount in figures] (PKR [Amount in words])
Contractor	[Full Name of Contractor]
PMC / Consultant	[Full Name of PMC / Consultant]
Client / Employer	Pakistan Airports Authority (PAA)
Prepared by	[Name], [Designation] – [Organisation]
Date of Issue	[DD Month YYYY]

DOCUMENT REVISION HISTORY

Rev.	Date	Description of Revision	Revised By
00	[Date]	Initial Issue	[Name / Designation]
01	[Date]	[Description]	[Name / Designation]

TABLE OF CONTENTS

TABLE OF CONTENTS	675
0. PROJECT DASHBOARD (SNAPSHOT)	676
0.1 Overall Progress Indicators	676
0.2 RAG Status	676
1. EXECUTIVE SUMMARY	677
1.1 Project Scope & Salient Features	677
1.2 Key Achievements This Month	677
1.3 Major Challenges & Issues	677
1.4 Critical Activities Undertaken	677
1.5 Scope / Schedule / Resource Changes	677
1.6 Major Targets for Next Month	677
2. FINANCIAL PROGRESS SUMMARY	678
3. PHYSICAL PROGRESS ACHIEVED THIS MONTH	679
3.1 Progress Summary Narrative	679
3.2 Detailed Progress Table	679
4. LOOK-AHEAD PLAN	680
4.1 One-Month Look-Ahead Target Table	680
4.2 Three-Month Rolling Look-Ahead Narrative	680
5. EARNED VALUE ANALYSIS (EVA)	681
5.1 EVM Trend Analysis	681
6. S-CURVE	682
7. MANPOWER & EQUIPMENT	683
7.1 Manpower Deployment Summary	683
7.2 Key Equipment Deployment & Productivity	683
8. HEALTH, SAFETY & ENVIRONMENT (HSE)	684
8.1 HSE Performance Statistics	684
8.2 HSE Observations & Environmental Compliance	684
9. CLIMATIC / WEATHER CONDITIONS	685
10. LABORATORY / TESTING DETAILS	686
10.1 Quality Trends & Analysis	686
11. SUBMITTAL STATUS	687
11.1 Material Submittals – Current Status	687
11.2 Method Statements & Shop Drawings – Current Status	687
11.3 Next Month – Target Submittals	687
12. CHALLENGES, RISKS & MITIGATION MEASURES	688
13. OPPORTUNITIES & RECOMMENDATIONS	689
14. CORRESPONDENCE & CONTRACTUAL EVENTS	690
15. ATTACHMENTS CHECKLIST	691
16. CERTIFICATION & SIGN-OFF	692

0. PROJECT DASHBOARD (SNAPSHOT)

This single-page snapshot is for senior management. Complete all cells before distribution.

0.1 Overall Progress Indicators

Indicator	Planned (%)	Actual (%)	Variance (%)	Remarks
Overall Physical Progress (Cumulative)	[]	[]	[]	[]
Physical Progress – This Month Only	[]	[]	[]	[]
Financial Progress (Cumulative)	[]	[]	[]	[]
ADP Utilisation – Current Year (%)	[]	[]	[]	[]

0.2 RAG Status

Parameter	Status	Remarks / Basis
Schedule	GREEN	[Remarks / basis for status]
Cost / Budget	AMBER	[Remarks / basis for status]
Quality	GREEN	[Remarks / basis for status]
HSE	GREEN	[Remarks / basis for status]
Submittals	AMBER	[Remarks / basis for status]
Procurement / Supply Chain	RED	[Remarks / basis for status]

RAG Key: GREEN = On Track | AMBER = At Risk, Monitoring Required | RED = Delayed / Off Track, Immediate Action Required

1. EXECUTIVE SUMMARY

1.1 Project Scope & Salient Features

Provide a brief description of project scope, key deliverables, and major contract features (2–4 sentences).

[Scope description]

1.2 Key Achievements This Month

- [Achievement 1 – be specific, measurable]
- [Achievement 2]
- [Achievement 3]

1.3 Major Challenges & Issues

- [Challenge / issue 1 – note impact on schedule / cost / quality]
- [Challenge / issue 2]

1.4 Critical Activities Undertaken

- [Critical activity 1 – include location and quantities]
- [Critical activity 2]

1.5 Scope / Schedule / Resource Changes

Note any formal Variation Orders, Extensions of Time, or resource re-deployments issued or under review this month.

[Detail any changes, or state 'No changes to scope, schedule or resources this month.']

1.6 Major Targets for Next Month

- [Target 1 – link to baseline schedule milestone]
- [Target 2]
- [Target 3]

2. FINANCIAL PROGRESS SUMMARY

All amounts in Pakistani Rupees (PKR) unless otherwise stated. Round to nearest thousand.

Financial Parameter	Amount (PKR)	% of PC-I Cost
Total Approved PC-I Cost	[Amount]	100%
Expenditure up to End of Last Financial Year	[Amount]	[]%
ADP Allocation – Current Financial Year	[Amount]	[]%
Expenditure in Current Financial Year (to date)	[Amount]	[]%
ADP Utilisation – Current Year (%)	—	[]%
Total Cumulative Expenditure / Payment to Date	[Amount]	[]%
Amount Accrued / Payable – This Month	[Amount]	[]%
Amount Accrued / Payable – Cumulative to Date	[Amount]	[]%
Retention Money Deducted (Cumulative)	[Amount]	[]%
Pending Invoices / Claims Under Review	[Amount]	—
Remaining Budget (PC-I Cost – Total Expenditure)	[Amount]	[]%
Projected Cash Flow – Next Month	[Amount]	—
Re-appropriation / Additional Funds Required	[Amount] / NIL	—

Attach financial bar chart (Planned vs. Actual vs. Remaining Budget) as Attachment F-1.

3. PHYSICAL PROGRESS ACHIEVED THIS MONTH

3.1 Progress Summary Narrative

Provide a 2–3 paragraph narrative per major sub-head summarising achievements and explaining variances.

[Narrative – Sub-Head 1]

[Narrative – Sub-Head 2]

3.2 Detailed Progress Table

Unit of Measurement (UOM) is mandatory. Cumulative (Previous Month) column enables independent verification.

Sr.	Sub-Head	BOQ Code	UOM	Activity / Work Description	Total Approved Qty	Cum. Qty (Previous Month)	Planned Qty (This Month)	Actual Qty (This Month)	Cum. Qty (This Month)	Progress vs. Planned (%)	Progress vs. Total (%)	Reason for Variance
1	[Sub-Head]	[Code]	[UOM]	[Description of Work]	[Qty]	[Qty]	[Qty]	[Qty]	[Qty]	[] %	[] %	[If <90%, state reason]
2	[Sub-Head]	[Code]	[UOM]	[Description of Work]	[Qty]	[Qty]	[Qty]	[Qty]	[Qty]	[] %	[] %	[If <90%, state reason]
3	[Sub-Head]	[Code]	[UOM]	[Description of Work]	[Qty]	[Qty]	[Qty]	[Qty]	[Qty]	[] %	[] %	[If <90%, state reason]

4. LOOK-AHEAD PLAN

4.1 One-Month Look-Ahead Target Table

Flag critical-path activities (CP = Yes). State responsible party and resources required.

Sr.	Sub-Head	BOQ Code	UOM	Activity / Work Description	Total Approved Qty	Cum. Qty to Date	Target Qty – Next Month	CP? (Y/N)	Predecessor Activity	Responsible Party	Resources Required (Man / Plant)
1	[Sub-Head]	[Code]	[UOM]	[Description]	[Qty]	[Qty]	[Qty]	[Y/N]	[Activity No.]	[Name / Team]	[Numbers]
2	[Sub-Head]	[Code]	[UOM]	[Description]	[Qty]	[Qty]	[Qty]	[Y/N]	[Activity No.]	[Name / Team]	[Numbers]
3	[Sub-Head]	[Code]	[UOM]	[Description]	[Qty]	[Qty]	[Qty]	[Y/N]	[Activity No.]	[Name / Team]	[Numbers]

4.2 Three-Month Rolling Look-Ahead Narrative

Provide a strategic narrative covering months T+1, T+2, and T+3 with focus on critical path activities, procurement milestones, and resource planning.

[Month T+1 – Key activities and targets]

[Month T+2 – Key activities and targets]

[Month T+3 – Key activities and targets]

5. EARNED VALUE ANALYSIS (EVA)

Populate all EVM metrics. Attach trend charts (SPI and CPI over time) as Attachment EV-1.

Ref.	EVM Metric	Formula	Value (PKR / Index)	Interpretation
BAC	Budget at Completion	Total Project Budget	[Value]	Baseline cost
PV	Planned Value	Budgeted cost of work scheduled	[Value]	Work planned by today
EV	Earned Value	Budgeted cost of work performed	[Value]	Work actually done
AC	Actual Cost	Actual cost of work performed	[Value]	Money spent to date
SV	Schedule Variance	$EV - PV$	[Value]	+ Ahead / - Behind
CV	Cost Variance	$EV - AC$	[Value]	+ Under / - Over
SPI	Schedule Performance Index	EV / PV	[Value]	>1 Ahead; <1 Behind
CPI	Cost Performance Index	EV / AC	[Value]	>1 Under; <1 Over
EAC	Estimate at Completion	BAC / CPI	[Value]	Projected final cost
ETC	Estimate to Complete	$EAC - AC$	[Value]	Remaining cost
VAC	Variance at Completion	$BAC - EAC$	[Value]	+ Saving / - Overrun
TCPI	To-Complete Performance Index	$(BAC - EV) / (BAC - AC)$	[Value]	Efficiency needed

5.1 EVM Trend Analysis

Comment on SPI and CPI trends over the last 3 months and actions taken to recover if indices are below 1.0.

[EVM trend narrative and recovery actions]

Attach: (a) SPI/CPI trend graph over project duration | (b) S-Curve (Planned vs. Actual physical & cost) – Attachment EV-1 & EV-2

6. S-CURVE

Attach two S-Curve graphs as Attachment SC-1 and SC-2 respectively:

- SC-1: Cumulative Physical Progress (%) – Planned Baseline vs. Actual vs. Forecast
- SC-2: Cumulative Financial Progress (PKR) – Planned Baseline vs. Actual Expenditure vs. Cash Flow Forecast

Both curves shall be updated monthly against the approved baseline schedule. Deviations of more than 5% from the baseline shall be annotated with a cause and recovery note.

[Insert S-Curve graphs here or cross-reference Attachment SC-1 and SC-2]

7. MANPOWER & EQUIPMENT

7.1 Manpower Deployment Summary

Compare deployed manpower against the approved baseline resource histogram. Highlight shortfalls.

Category	Planned (Peak)	Deployed This Month	Variance	Peak This Month	Remarks
Engineers / Technical Staff	[]	[]	[]	[]	[]
Supervisors	[]	[]	[]	[]	[]
Skilled Labour	[]	[]	[]	[]	[]
Unskilled Labour	[]	[]	[]	[]	[]
Machinery Operators	[]	[]	[]	[]	[]
Sub-contractor Personnel	[]	[]	[]	[]	[]
Total	[]	[]	[]	[]	[]

7.2 Key Equipment Deployment & Productivity

Report availability (%), utilisation (%), and output. Flag underperforming equipment.

Equipment Type	No. on Site	No. Working	Monthly Op. Hours	Availability (%)	Utilisation (%)	Output Rate (per Hr/Day)	Total Output	Remarks / Issues
Concrete Batching Plant	[]	[]	[]	[]	[]	[]	[]	[]
Asphalt Batching Plant	[]	[]	[]	[]	[]	[]	[]	[]
Concrete Pavers	[]	[]	[]	[]	[]	[]	[]	[]
Asphalt Pavers	[]	[]	[]	[]	[]	[]	[]	[]
Excavators	[]	[]	[]	[]	[]	[]	[]	[]
Dump Trucks	[]	[]	[]	[]	[]	[]	[]	[]
Compactors	[]	[]	[]	[]	[]	[]	[]	[]
Cranes	[]	[]	[]	[]	[]	[]	[]	[]
Other Key Plant	[]	[]	[]	[]	[]	[]	[]	[]

8. HEALTH, SAFETY & ENVIRONMENT (HSE)

8.1 HSE Performance Statistics

HSE Metric	This Month	Cumulative to Date
Total Man-Hours Worked	[]	[]
Fatalities	[]	[]
Lost Time Injuries (LTI)	[]	[]
Medical Treatment Cases (MTC)	[]	[]
Near Misses Reported	[]	[]
Unsafe Acts / Conditions Reported	[]	[]
Accident Frequency Rate (AFR)	[]	[]
Accident Severity Rate (ASR)	[]	[]
HSE Inspections Conducted	[]	[]
Toolbox Talks Conducted	[]	[]
HSE Trainings Conducted	[]	[]
Non-Conformances (NCRs) Issued	[]	[]
NCRs Closed	[]	[]
Environmental Incidents	[]	[]

8.2 HSE Observations & Environmental Compliance

Note any significant HSE incidents, corrective actions, and ESMP compliance status.

[HSE narrative and corrective actions]

9. CLIMATIC / WEATHER CONDITIONS

Record daily climatic data. Skardu is high-altitude (approx. 2,228 m ASL) – temperature, snowfall, and wind are critical. Provide a monthly summary row at the bottom.

Date	Max Temp (°C)	Min Temp (°C)	Avg Temp (°C)	Humidity (%)	Wind Speed (km/h)	Wind Direction	Rainfall / Snowfall (mm)	Site Working? (Y/N)	Remarks / Impact on Work
[Date]	[]	[]	[]	[]	[]	[]	[]	[]	[]
[Date]	[]	[]	[]	[]	[]	[]	[]	[]	[]
[Date]	[]	[]	[]	[]	[]	[]	[]	[]	[]
MONTHLY SUMMARY	[Average / Total]	[Average / Total]	[Average / Total]	[Average / Total]	[Average / Total]	[Average / Total]	[Average / Total]	[Average / Total]	[Average / Total]

Note: Record number of working days lost due to adverse weather. Attach meteorological records if available.

10. LABORATORY / TESTING DETAILS

Reference the applicable test standard/specification for each test type. Failed tests must have a Corrective Action noted.

Test Type	Test Standard / Spec. Ref.	Required Frequency	Tests This Month	Tests Passed	Tests Failed	Cum. Pass Rate (%)	Status	Corrective Action / Remarks
Soil Compaction (Proctor)	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]
Concrete Compressive Strength	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]
Asphalt Core / Marshall Test	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]
Aggregate Grading & Quality	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]
Concrete Mix Design Verification	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]
Rebar Tensile Test	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]
Other	[ASTM / BS ref.]	[Freq.]	[]	[]	[]	[]%	[Pass / Fail / Pending]	[Action if failed]

10.1 Quality Trends & Analysis

Identify any recurring failure trends and their impact on schedule and quality. Note corrective measures.

[Quality trend narrative]

11. SUBMITTAL STATUS

Track both Material Submittals and Method Statement / Shop Drawing submittals separately. Per Contract Clause [X.X], a maximum of three (3) approvals are permitted per material item and total submission attempts shall not exceed five (5).

11.1 Material Submittals – Current Status

Sub. No.	Material Description	Submission Date	Engineer Response Date	Status (Approved / Rejected / Pending)	Attempt No. (1st/2nd/3rd)	Remaining Attempts	Resubmission Target Date	Reason for Rejection (if any)	Impact on Progress if Unresolved	Remarks
[S-001]	[Material Name]	[Date]	[Date]	[Status]	[1st]	[2]	[Date]	[Reasons stated by Engineer]	[High / Medium / Low]	[]
[S-002]	[Material Name]	[Date]	[Date]	[Status]	[1st]	[2]	[Date]	[Reasons stated by Engineer]	[High / Medium / Low]	[]
[S-003]	[Material Name]	[Date]	[Date]	[Status]	[1st]	[2]	[Date]	[Reasons stated by Engineer]	[High / Medium / Low]	[]

11.2 Method Statements & Shop Drawings – Current Status

Sub. No.	Description	Submission Date	Engineer Response Date	Status	Resubmission Target Date	Impact of Delay	Remarks
[MS-001]	[Method Statement / Shop Drawing Title]	[Date]	[Date]	[Approved/Rejected/Pending]	[Date]	[High/Medium/Low]	[]
[MS-002]	[Method Statement / Shop Drawing Title]	[Date]	[Date]	[Approved/Rejected/Pending]	[Date]	[High/Medium/Low]	[]

11.3 Next Month – Target Submittals

Sub. No.	Description	Type (Material / MS / SD)	Target Submission Date	Target Approval Date	Impact if Delayed	Remarks / Dependencies
[S-004]	[Description]	[Type]	[Date]	[Date]	[High/Medium/Low]	[]
[S-005]	[Description]	[Type]	[Date]	[Date]	[High/Medium/Low]	[]
[S-006]	[Description]	[Type]	[Date]	[Date]	[High/Medium/Low]	[]

12. CHALLENGES, RISKS & MITIGATION MEASURES

Link each entry to the Project Risk Register. Assign a Risk Owner and Target Resolution Date.

Sr.	Risk Reg. Ref.	Category	Probability (H/M/L)	Impact (H/M/L)	Description	Impact on Project (Time / Cost / Quality)	Mitigation Measures (Implemented / Planned)	Risk Owner	Target Resolution Date	Status (Open / Closed)
1	RR-001	Challenge	H	H	Material delivery delays – supply chain constraints	Time – schedule slippage	Engage alternate suppliers; adjust work sequencing	Contractor PM	[Date]	Open
2	RR-002	Challenge	M	H	Adverse weather – high-altitude Skardu conditions	Time / Cost	Reschedule critical activities; deploy protection	Site Engineer	[Date]	Open
3	RR-003	Risk	M	M	Design modifications during execution	Cost / Time	Early design reviews; streamline approval workflow	Consultant	[Date]	Open
4	RR-004	Risk	L	H	Regulatory / authority approval delays	Time	Continuous liaison; early submission of documents	Project Director	[Date]	Open

13. OPPORTUNITIES & RECOMMENDATIONS

Sr.	Opportunity Identified	Potential Benefit (Time / Cost / Quality / Efficiency)	Recommended Action Steps	Responsible Party	Target Date
1	Integrated PM software for real-time tracking	Efficiency – better monitoring	Implement digital project monitoring tools	Contractor / PMC	[Date]
2	Framework agreements for procurement	Cost / Time – reduced delays	Digitise procurement & establish supplier agreements	Contractor	[Date]
3	Enhanced stakeholder coordination	Quality / Time	Regular coordination meetings; centralised comms	PMC / PAA	[Date]
4	Prefabrication for repetitive elements	Time / Quality	Pilot prefab components; assess cost-benefit	Contractor	[Date]
5	Staff training & certification	Quality / Efficiency	Targeted training programmes on critical skills	Contractor	[Date]

14. CORRESPONDENCE & CONTRACTUAL EVENTS

Record all formal correspondence, instructions, and contractual events issued or received during the reporting month.

Sr.	Ref. No.	Type (VO / EOT / ITT / NCR / Letter)	Date Issued	Issued By	Description / Subject	Impact (Time / Cost)	Status (Open / Closed / Under Review)
1	[Ref.]	[Type]	[Date]	[Party]	[Subject / Brief Description]	[Impact]	[Status]
2	[Ref.]	[Type]	[Date]	[Party]	[Subject / Brief Description]	[Impact]	[Status]
3	[Ref.]	[Type]	[Date]	[Party]	[Subject / Brief Description]	[Impact]	[Status]

15. ATTACHMENTS CHECKLIST

Tick each attachment included with this report. Unticked items must be noted as 'N/A' or 'Deferred to MPR [No.]'.

Att. Ref.	Included? (Y/N/NA)	Description	No. of Pages / Sheets	Remarks
GC-1	Y/N	Updated Master Programme (Primavera / MS Project extract with progress lines vs baseline)	[]	[]
GC-2	Y/N	Project Gantt Chart – Critical Path highlighted	[]	[]
GC-3	Y/N	Meeting Minutes – Monthly Progress Review Meeting	[]	[]
F-1	Y/N	Financial Bar Chart – Planned vs. Actual vs. Remaining Budget	[]	[]
EV-1	Y/N	EVM Trend Graph – SPI and CPI over project duration	[]	[]
EV-2	Y/N	S-Curve – Cumulative Physical Progress (Planned vs. Actual vs. Forecast)	[]	[]
SC-1	Y/N	S-Curve – Cumulative Financial Progress (Planned vs. Actual vs. Cash Flow)	[]	[]
MP-1	Y/N	Manpower Deployment Records (Attendance Sheets – Monthly Compiled)	[]	[]
PH-1	Y/N	Site Photographs (labelled with location, date and activity)	[]	[]
QA-1	Y/N	Laboratory / Testing Records and Test Reports	[]	[]
QA-2	Y/N	Non-Conformance Reports (NCRs) – Open and Closed This Month	[]	[]
HSE-1	Y/N	HSE Inspection Reports and Toolbox Talk Records	[]	[]
HSE-2	Y/N	Accident / Incident Reports (if any)	[]	[]
SUB-1	Y/N	Submittal Register – Updated	[]	[]
VAR-1	Y/N	Variation Orders / Change Orders Issued or Under Review This Month	[]	[]
CORR-1	Y/N	Formal Correspondence Register – Monthly Update	[]	[]

16. CERTIFICATION & SIGN-OFF

This Monthly Progress Report has been prepared, reviewed, and approved by the authorised representatives of the respective organisations as indicated below. The information contained herein is certified to be accurate and complete to the best of the signatory's knowledge.

Role	Name	Designation	Organisation	Signature	Date
Prepared by	[Full Name]	Resident Engineer / Project Manager	Contractor		
Reviewed by	[Full Name]	Project Manager / Senior Engineer	PMC / Consultant		
Endorsed by	[Full Name]	Project Director	PAA – P&D Directorate		
Approved by	[Full Name]	Director (Planning & Development)	Pakistan Airports Authority		

**LIST OF APPROVED MANUFACTURERS
OF AIR TRAFFIC CONTROL TOWER AT SKARDU INTERNATIONAL AIRPORT.**

(To be signed by the Bidder)

The Contractor should note that only material from those manufacturers specified in the list of approved manufacturers shall be allowed to be used on this Project. The Contractor shall submit literature/catalogue/samples etc. of all the items from each of the specified manufacturer to the Engineer who shall then decide and approve the sample and the manufacturer. Where the item involves any finishes such as paints, external coatings, etc. the Contractor shall erect mock-up samples of the specified manufacturers for the selection and approval of the Engineer.

The responsibility lies with the Contractor for establishing the genuineness of any materials/products/items for its make and origin as specified below.

CIVIL WORKS		
Sr. No.	Materials / Items	Name of Manufacturer/ Suppliers
1	Cement	1. DG Cement 2. Maple Leaf Cement 3. Pioneer Cement 4. Best way Cement 5. Lucky Cement.
2	Steel (60 Grade & 40 Grade)	1. Sheikhoo Steel 2. FF Steel 3. Moiz Steel 4. Ittefaq Steel 5. Nomee Steel 6. Amreli Steel
3	Aluminum Works (Aluminum Doors & Windows)	1. Chawala Aluminum 2. Prime Aluminum
4	Glass	1. Guardian Glass 2. Emirates Glass 3. Saint Gobain Glass 4. AGC Glass
5	U.P.V.C Windows	1. Wintech, 2. Veka 3. Yagmur Pen
6	Paints	1. ICI Paints 2. Happilac Paints 3. Nippon Paints 4. Jotun Paints
7	Wall Coatings	1. Rock Shield 2. Fanaan by Brighto 3. Happilac 4. Nova Color
8	Thermal Insulation	1. Diamond Jumbolon

9	Glass Mosaic Tile	1. AMC Art Design 2. MEC Mosaic.
10	Concrete Floor Tiles. Pavers &. Paving Blocks	1. Concrete Concept 2. ENVICRETE 3. Fine Concrete
11	Porcelain Tiles on Floor & Toilets	1. Fifi Ceramic by S. Abdullah 2. Porcelanosa by AW 3. Atlas Concorde by AW 4. Novus by H-Verse 5. Monalisa by H-Verse 6. Aura by Hadayat Sons 7. Aive by H-verse 8. Orient Ceramics
12	Ceramic Tiles in Toilets	1. Fifi Ceramic 2. Porcelanosa by AW 3. Atlas Concorde by AW 4. Novus by H-Verse 5. Monalisa by H-Verse
13	PVC Tiles (Static)	1. Marflex 2. Sarina Flooring
14	PVC Tiles (Non-Static)	1. Marflex 2. Sarina Flooring
15	Water Stopper	3. Marflex
16	Epoxy Coating / Flooring	1. Aqua Seal 2. Sika 3. Vertex 4. Happilac
17	Facade Tile / System	1. Novus by H-verse 2. Kuthaya by S-Abdullah 3. Sinterflex Turkish
18	Termite Proofing (For Soil)	1. Agenda by Jaffer Brothers 2. BruckMann 3. Safe Posion by Mass Brown
19	Termite Proofing (For Wood)	1. Bio-Wood 2. Kanzo (Urban Pest) 3. Power-Max 4. Dow Agro Sciences 5. Solegnium 6. Jaffer Brothers
20	Water Proofing	1. Aqua Seal 2. Sika
21	Aluminum Lineal False Ceilings	1. Daiken (Japan) 2. Dampa (Denmark) 3. Owa (Germany)
22	Doors, Kitchen Cabinets	1. Interwood 2. Naeem Trading Company 3. Buro Kitchen
23	WPC Doors	1. Esta Doors

24	EPC Panels	2. Banu Mukhtar 3. EPC Solution Pakistan
25	Door Locks & Door Closer	1. Yale 2. Abloy
26	Tile Grout	1. Happilac 2. Sika
27	Tile Bond	1. Happilac 2. Sika
28	Gypsum Board Ceiling and Panel	1. United Gypsum 2. Elephant 3. Lodhiya Gypsum
29	Fire Doors	1. Haseen Habib 2. Khokhar Group
30	Terrozzo Tiles	1. Punjab Tiles
31	Expansion Joints	4. ARFEN 5. Asteknik 6. Mesihuo
32	Expanded Polystyrene (EPS) / PIR Panel	1. Banu Mukhtar 2. EPS Pakistan 3. Izhar Foster
33	Space Frame Structure	1. OHC Construction China 2. ABC Engineering Company China 3. Jazari Steel Pvt Ltd
WATER SUPPLY & SANITARY FITTINGS		
Sr. No.	Materials / Items	Name of Manufacturer/ Suppliers
1	G.I. Pipes	1. M/S International Industries Limited (IIL)
2	G.I. Pipe Fittings	1. M/S HE China, M/S TG China.
3	CPVC Pipes	1. Prestige Plastic Pipes 2. Labrasol 3. Stealex Pipes
4	Sanitary Fixtures	1. TOTO by AW 2. Verona by H2O 3. Bleen by H-Verse 4. Sera by S-Abdullah
5	Kitchen Sinks	1. RAK 2. Fatile 3. Franke
6	Sanitary Fittings	1. TOTO by AW 2. Hans Grohe by H-Verse 3. SERA by S- Abdullah
7	Valves	1. Kitj-Japan
8	Geyser	1. Ekotherm 2. CANNON 3. Veissman

9	Water Cooler	1. Deluxe, 2. Ambassador, 3. CANON
10	C.I. Covers With Frame Floor Drains & Floor Cleanouts	1. Alpine Steel (Pvt.) Ltd. 2. Sandal Engineering (Pvt.) Ltd. 3. Central Mechanical Engineering (CME) Company (Pvt.) Ltd.
11	Fire Hose Cabinet And Extinguishers + Fire Doors	1. M/S Haseen Habib (Pvt.) Ltd. 2. MESI GROUP
12	UPVC , HDPE & PPRC Pipes and Fittings	1. M/S Shafisons Engineering (Pvt.) Ltd. (Beta Pipes). 2. IIL 3. Master Pipes (Faisalabad), 4. Popular Pipes
13	Electric Water Heaters.	1. CANON 2. Nas Gas
14	Water Filters	1. M/S So-Safe 2. M./S Aqua Safe 3. Culligan 4. Teka

ELECTRIC MATERIAL		
Sr. No.	Materials / Items	Name of Manufacturer/ Suppliers
1	Light Fixture	1. Impulse 2. Watts and Luxes 3. Fast Lighting 4. Matrix Led
2	Distribution Boards, Main & Sub-Main Panel Boards	1. Bilal Switch Change 2. Electrech 3. Volamp Engineering 4. Capital Switch gear
3	Cables And Wires	1. Pakistan Cables 2. Newage Cables 3. Fast Cables 4. CopperGat Cables
4	PVC Conduit & Accessories	1. Beta 2. Master Pipes (Faisalabad)
5	Steel Conduit & Accessories	1. M/S International Industries Limited (IIL)
6	Switches. Sockets Etc.	1. ORANGE 2. Legrand 3. Schneider
7	Back Boxes, Pull Boxes, Etc.	1. Bosch 2. Milano 3. Legrand 4. ORANGE
8	Telephone Cables Dish Antenna Cables	1. Siemens Germany 2. Comscope USA & 3 M

		3. Ventilex
9	Telephone Junction Boxes	1. Panasonic 2. Huawei
10	Fans	1. GFC Fans 2. Lahore Fans 3. Royal Fans
11	MCCBS And MCBS	1. Marlin Gerlin (MG) (France) 2. Siemens (Germany) 3. ABB (Italy) 4. Schneider Electric (Germany) 5. ORANGE
12	ACBS	1. Siemens (Germany) 2. ABB (Italy)
13	Generator Set	1. Caterpillar 2. Siemens 3. Power zone by Mecatech
14	Transformer	1. Siemens 2. PEL
15	CCTV System & Public Address System	1. Hik Vision 2. Samsung 3. Sony 4. Dahua
16	DC Inverter and Air Conditioner	1. Trane 2. TCL 3. Hitachi 4. Daikin
17	Solar System Panels	1. Longi Solar 2. Jinko Solar 3. Canadian Solar
18	Solar System Inverter	1. Solis 2. Huawei
19	Net Working Cables	1. ORANGE 2. 3M

Authorized Signature and official Seal: _____

Name: _____

Date: _____