MMCSA-SP0001

Canadian Space Agency

MULTI-MISSION OPERATION CENTER (MMOC)

Multi-Mission Antenna Reservation System (ARS) Requirements Document

Revision 1.0

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PREFACE

This document and all changes to it shall be submitted to the author and be approved by the Canadian Space Agency (CSA)'s Multi-Mission Operation Center manager. Proposed changes to the currently approved baselined version of this document shall be forwarded to the Satellite Operations Configuration Management (CM) Receipt Desk for evaluation and submission for approval. Approved changes shall be incorporated in the next revision.

Prepared by:	Jean-François Lévesque Ground System Operations Engineer Space Utilization	February 6, 2014 Date
Reviewed by:	Patrice Côté Senior Systems Engineer Space Science and Technology	Date
Approved by:	Michel Doyon Flight Operation Manager Space Utilization	Date

REVISION HISTORY

Rev.	Description	Initials	Date
1.0	Initial Release Released by the approval of CSA CR ##	PC / JFL	February 6, 2014

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE PAGE

LIST OF TABLES

TABLE PAGE

1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to specify the design requirements of the Antenna Reservation System (ARS) addressing the need for antenna resource coordination in the context of a multi-mission satellite control center. The ARS is functional sub-system as part of the CSA's Multi-Mission Operation Center (MMOC) architecture. With respect to the RADARSAT Constellation Mission (RCM), the ARS is also a sub-system component of the Government Furnished Equipment (GFE) in support of the overall RCM Ground Segment (GS).

1.2 SCOPE

The ARS Requirement Document (SRD) shall comply with the requirements of actual missions and missions under development such as the RCM. This document comes with the ARS companion Interface Control Document (ICD) (AD-1), which describes the interfaces with both the satellite missions and the ground station facilities.

1.3 APPLICABILITY

This document is applicable to the ARS companion ICD (AD-1) and to both the supported Mission and Facilities interface, in which case:

- All supported Missions will be flexible to accommodate the ARS interface, namely: Scisat, NEOSSat, M3MSat, and RCM,
- All supported Internal Facilities will accommodate the ARS interface; there is currently no Internal Facility,
- All supported RCM Canadian Facilities (External Facilities) will be flexible to accommodate the ARS interface, namely:
    - CCMEO's Prince-Albert (PASS), Gatineau (GSS) and Inuvik (INSS) (SXGT),
    - Polar-Epsilon 2 Facilities in Aldergrove (CAAL) and Masstown (CAMA), and
- The ARS will be flexible to accommodate all other expected External Facilities, which become applicable to this document, namely:
    - MDA's St-Hubert (SHUB) and Saskatoon (SASK) Facilities,
    - DRDC Shirley's Bay Satellite Facility (DRDC) in Ottawa,
    - KSAT's Facility operated from Norway,
    - SSC Facilities operated from Kiruna, Sweden,
    - DLR Facilities operated from Oberpfaffenhofen, Germany, and
    - CNES Facilities.

Scheduling for radar transponders and Data Reception (DR) Network Stations like the ones used by RADARSAT-1 are managed by their respective Missions and **is outside the scope of the ARS**.

2 DEFINITIONS

2.1 ACRONYMS AND ABBREVIATIONS

ACS	Attitude Control System
AD	Applicable Document
AOS	Acquisition of Signal
ARS	Antenna Reservation System
CAAL	Canadian Aldergrove Facility
CAMA	Canadian Masstown Facility
CCMEO	Canada Centre for Mapping and Earth Observation
CM	Configuration Management
CNES	Centre National d'Études Spatiales
CSA	Canadian Space Agency
DCS	De-Conflict System
DLR	Deutches Zentrum für Luft- und Raumfart (German Space Agency)
DR	Data Reception
DRDC	Defence Research and Development Canada
GFE	Government Furnished Equipment
GS	Ground Segment
GSS	Gatineau Satellite Station
GUI	Graphic User Interface
ICD	Interface Control Document
ID	Identification
INSS	Inuvik Satellite Station
KSAT	Kongsberg Satellite Services
LEOP	Launch and Early Operations Phase
LOS	Loss of Signal
MDA	MacDonald, Dettwiler and Associates Ltd.
MMOC	Multi-Mission Operation Center
MPS	Mission Planning Subsystem
NGT	Northern Ground Terminal
NORAD	North American Aerospace Defense Command
NRT	Near-Real-Time
PASS	Prince-Albert Satellite Station
PD	Parent Document
PE2	Polar Epsilon 2

RCM	RADARSAT Constellation Mission
RD	Reference Document
RF	Radio Frequency
RNG	Ranging
RT	Real-Time
SAR	Synthetic Aperture Radar
SASK	Saskatoon Facility
SCS	Satellite Control Subsystem
SF	Store and Forward
SHUB	St-Hubert Facility
SRD	System Requirement Document
SSC	Swedish Space Corporation
SXGT	S-Band and X-Band Ground Terminal
TBC	To Be Confirmed
TBD	To Be Determined
TC	Telecommand
TLE	Two-Line Elements
TM	Telemetry
TT&C	Telemetry, Tracking & Commanding
XML	Extensible Markup Language

2.2 TERMINOLOGY

TABLE 2-1 TERMINOLOGY DEFINITIONS

System	Is the physical implementation (hardware and software) of the ARS functionalities. (Note: In addition to the System, the overall ARS may include other elements such as a Backup System, the Operator interface, the network connectivity, the voice interface, the System maintenance, the programmatic layer, etc.).
Operator	Is the personnel that commands and controls the System. The Operator has delegated rights to operate the ARS, approve Schedules, generate or edit Configurations, modify scheduling rules and algorithms, and manually reserve Antenna time.
Antenna	Is composed of a tracking dish reflector with RF components and baseband equipment required to conduct ranging, TT&C and/or Data Reception (DR) operations for a satellite mission.
Facility	Consists of one or multiple unique ground station Antennas, and appropriate equipment to conduct either or both TT&C and DR operations. Facilities exclude transponders and Network Stations like the ones used by RADARSAT-1.
Internal Facility	Is a Facility that is owned and operated by the CSA. It is assumed that Internal Facilities will be controlled by the ARS Operator.
External Facility	Is a Facility, domestic or foreign, that is controlled by a third-party organization.
Network Station	Is an Antenna station used for local DR of commercial data dedicated to a commercial client of a given Mission. Network Station is not considered a schedulable Facility in the scope of the ARS.
Mission	Consists of one or multiple Earth orbiting Satellites, and appropriate ground segment functional elements required to conduct the mission operations such as the Mission Planning Subsystem (MPS).
Satellite Orbital Ephemeris	Is the orbital ephemeris information required to propagate a Satellite's orbit and that is translated in a standard message format like the NORAD Two-Line Elements (TLE).
Satellite Contact	Is the time period where the Mission Satellite have a contact line-of-sight with a Facility Antenna resource, and which the resource can be allocated to the Mission on a Schedule.
Contingency Contact	Is a backup or alternate Satellite Contact to a nominal one that occurs on another Antenna within a defined time window.
Compliant Contact	Is a contact that satisfies all the System, Mission and Facility Configuration Constraints while being a valid contact as propagated

	from the Satellite Orbital Ephemeris.
Accepted Contact	Is the status of a requested Satellite Contact from an Antenna Access Request that has been accepted by the Facility.
Committed Contact	Is the status of a Satellite Contact that has been accepted by the Facility and committed by the ARS.
Deleted Contact	Is the status of a previously requested Satellite Contact that has been deleted by the Mission on a subsequent Satellite Contact Request.
Rejected Contact	Is the status of a requested Satellite Contact that has been rejected either by the Facility or by the ARS.
Cancelled Contact	Is the status of a previously Accepted or Committed Satellite Contact that has now been cancelled by the Facility for exceptional reasons.
Rescheduled Contact	Is the status of a requested Satellite Contact that has been rejected either by the Facility or by the ARS and that has been automatically rescheduled from another available Contact by the ARS.
Locked Contact	Is a Committed Contact that has been Locked by the operator to prevent any future automatic unallocation or rescheduling by the System.
Contact Criticality	Is the qualifier of a Contact that allows prioritization during the de-conflicting process in the computation of a Schedule. Criticality levels could be defined as Critical, Important and Routine.
Critical Contact	Relates to spacecraft Health & Safety (launch, collision avoidance, satellite recovery).
Important Contact	Relates to time-sensitive or emergency operations of the Mission (Fast-Tasking, Near-Real-Time (NRT) download, disaster monitoring, national security).
Routine Contact	Relates to all other Contacts.
Proficiency Contact	Relates to a contact that is required for periodical or ad-hoc validation and testing of the end-to-end ground systems with a specific Facility.
Satellite Contact Request	Is a list of desired Satellite Contacts that are requested by the Mission for allocation by the System on the Schedule. A Request may also include added, removed and modified Contacts from a previous Request with respect to the same time window.
Request Validity Report	Is a Satellite Contact Request that was checked and validated by the System against a Compliant Satellite Contact List. The Report includes an invalidity explanation field.
Compliant Satellite Contact List	Is the list of all Compliant Contacts for all Satellites and all Antennas generated by the ARS propagator and associated with a defined

	Schedule time window.
Antenna Access Request	Is a list of time periods where the System requests access to Facility Antenna resources in support of Missions.
Request Acknowledgment	Is a return message acknowledging reception of a Satellite Contact Request by the ARS or Antenna Access Request by the Facility.
Request Confirmation	Is a return message accepting, rejecting or cancelling Contacts from the Schedule of an Antenna Access Request.
Antenna Unavailability Report	Is a list of time periods where the Facility Antenna is not available for allocation to a Mission.
Schedule	Is a list of time-tagged Satellite Contacts for all Missions that have been allocated amongst the pool of Facility Antennas. A Schedule is conflict-free, that is only a single Satellite Contact is allocated at any given time to an Antenna. It contains in addition a set of fields describing for each Contact, the Mission Satellite ID, the Facility Antenna ID, the Acquisition of Signal (AOS) time, Contact duration, Loss of Signal (LOS) time, Satellite RF On/Off time, maximum antenna elevation, RF bands, RF data rate, etc.
Preliminary Schedule	Is a Schedule that has been generated by the System but is pending Operator's approval before sending requests to Facilities.
Approved Schedule	Is a Preliminary Schedule that has been approved by the Operator for access request to External Facilities.
Accepted Schedule	Is a Schedule containing all Accepted Contacts from Facilities but is pending Operator's final commitment.
Committed Schedule	Is an Accepted Schedule that has been approved by the Operator for distribution to Missions and Internal Facilities.
Obsolete Schedule	Is a Schedule that has been overruled by a new Committed Schedule.
Antenna Schedule	Is a subset of the Schedule that represents only the Satellite Contacts and fields relevant to a Facility.
Satellite Contact Schedule	Is a subset of the Schedule that represents only the Satellite Contacts and fields relevant to a Mission.
Performance Report	Is a summary of Mission requirements fulfillment and Facility usage resulting from a specific Schedule. This may include the total time allocated for each Mission Satellite on Facility Antennas, the unallocated/reallocated Satellite Contacts from Requests, and relative figures of merit of allocation time and requirement fulfillment.
Antenna Reservation Performance Report	Is a subset of the Performance Report that displays the specific Antenna usage relevant to a Facility.

Satellite Contact Performance Report	Is a subset of the Performance Report that displays the Satellite Contact allocation relevant to a Mission.
Configuration	Is a set of user-configurable parameters that captures the definition, constraints and requirements of a Facility, a Mission or the System . Its format could be stored as readable, binary or XML file, or simply captured by a user interface. Every System, Facility and Mission Configuration use their respective structure type but each individual has its unique parameter Configuration.
Configuration Constraints	Is a subset of the Configuration parameters that specifically addresses constraints to be used during orbit propagation and also for validation of Satellite Contact Requests.
Configuration Requirements	Is a subset of the Configuration parameters that specifically addresses minimal Mission autonomous scheduling requirements to be met when the Mission does not provide a Satellite Contact Request or to be taken into account during rescheduling of Contacts. This also proves useful for keeping regular contacts with a Satellite for health monitoring when there is only little mission operations needed over a long period of time.

3 DOCUMENTS

3.1 APPLICABLE DOCUMENTS

The following documents of the exact issue date and revision level shown are applicable and form an integral part of this document to the extent specified herein.

Ref #	Document Number	Revision	Title
AD-1	MMCSA-IC0003	0/1	Antenna Reservation System ICD
AD-2		1.0	KSAT Scheduling and Post Pass Reporting ICD
AD-3			KSAT Scheduling – XML format description for customers
AD-4			KSAT Acquisition availability – XML format description for customers
AD-5	MMCSA-IC0002	C	Live Schedule Board ICD

Note: Without their respective ICD, it is assumed that the interfaces of SASK, SHUB, DRDC and PE2 Facilities will conform to AD-1.

3.2 REFERENCE DOCUMENTS

The following documents provide additional information or guidelines that either may clarify the contents or are pertinent to the history of this document.

Ref #	Document Number	Revision	Title
RD-1	RCM-IC-53-1948	1/3	RCM Reservation System ICD
RD-2	RCM-SP-52-3334	3/1	RCM Ground Segment Requirements Specification
RD-3	RCM-SP-52-3987	4/3	RCM System Requirement Specification
RD-4	RCM-DD-52-8796	1/6	RCM Ground Segment Design Document
RD-5	RCM-IC-52-7885	1/7	RCM TT&C, EGSE, and SIM ICD
RD-6	RCM-IC-52-7777	2/6	RCM External Reception Facility/External Processing Facility ICD
RD-7	RSCSA-IC0015	E	Deconflict System Tool (DCS) Interface Design Specification
RD-8	RJ-IC-51-0929	4/0	Reception, Archiving and Cataloguing Controller (RACC) ICD

4 ARS OVERVIEW

The ARS is a multi-mission tool part of the MMOC necessary to coordinate antenna resource allocation to multiple satellite missions. The ARS becomes more necessary when the number of satellites sharing the same pool of available antenna increases and when conflicts to antenna resource access occur more frequently. The ARS is therefore responsible to receive contact time requests from missions and best meet all mission requirements by carefully reserving antenna time to the various missions on a priority and performance basis.

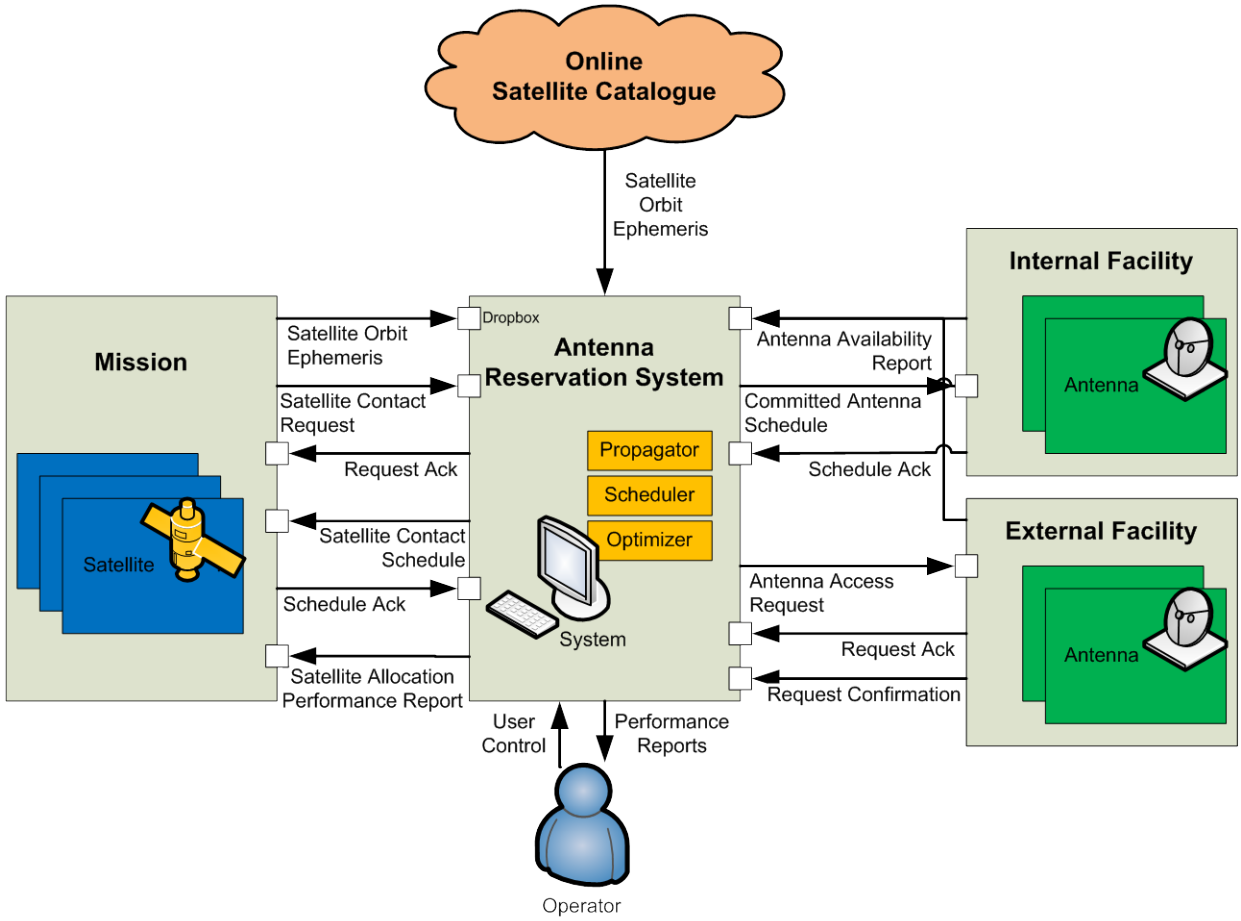


FIGURE 4-1 ARS OVERVIEW

The ARS may be seen as the central point where all mission requests for antenna time using a single reservation system and where all facility resources are allocated for both TT&C and DR (For a detailed process flow diagram, refer to Appendix A). The ARS does not deal with actual satellite operation requirements or direct commanding interfaces between the missions and the facilities (like the Spacecraft Control Subsystem (SCS)). However, the ARS does provide missions with a central antenna reservation tool to coordinate all Satellite Contacts and mitigate conflicts. In addition, the ARS does provide one interface definition to the missions therefore saving the missions from having to manage several scheduling interfaces with the various facilities. Finally, the ARS provides one point of decision making, through the Operator and

user-configurable System Configurations, when it's the time to handle different contact priority levels and mitigate conflicts.

4.1 OPERATIONAL SEQUENCE OF EVENTS

The ARS typical nominal sequence of events goes as follow:

Event 1. Missions asynchronously send unsolicited Satellite Contact Requests and Satellite Orbital Ephemeris to the ARS. Facilities asynchronously send Antenna Unavailability Reports to the ARS.

Event 2. Every time a Satellite Contact Request is received, the ARS submits the Request to the Operator for modification and approval.

Event 3. In parallel, the ARS propagates the orbits from Satellite Orbital Ephemeris and generates the List of all Satellite Contacts opportunities that are compliant to Mission and Facility Constraints.

Event 4. The ARS verifies the validity of all Contacts in the Satellite Contact Request against the Compliant Satellite Contact List and then sends back a reception acknowledgement message to the Mission. (Note that this Event may not be pending resolution of Event 2 and may occur in parallel.)

Event 5. The Operator may at this point directly reserve Contacts from the Compliant Satellite Contact List, with superseding priority over the Satellite Contact Requests.

Event 6. From the remainder Antenna availability of Event 5, the ARS then de-conflicts and computes a Preliminary Schedule from all the Satellite Contact Requests and Mission requirements based on priority and performance factors.

Event 7. The ARS submits the Preliminary Schedule to the Operator for approval.

Event 8. The ARS sends the Approved Schedule to External Facilities as Antenna Access Requests.

Event 9. External Facilities reply with a Request reception acknowledgement and send an Accepted Schedule as a Request Confirmation.

Event 10. The ARS submits the Accepted Schedule from the Facilities to the Operator for commitment.

Event 11. The ARS distributes the Committed Schedule to Missions and Internal Facilities.

Event 12. Missions and Internal Facilities reply with a Schedule reception acknowledgement.

Event 13. The ARS sends Performance Reports to Missions and to the Operator.

In parallel to the whole sequence of events, the ARS retrieves periodically the Satellite Orbital Ephemeris from online satellite catalogues to make sure the information is always up to date in case the Mission doesn't send it during Event 1.

Also, at any time, the Operator can manually abort and start the computation of a Preliminary Schedule, thus forcing the re-execution of the Sequence from Event 3.

For a detailed process flow diagram, refer to Appendix A.

5 ARS REQUIREMENTS

5.1 FUNCTIONAL REQUIREMENTS

[ARS010] Primary objective: The ARS shall manage Facility resource allocation for all supported Missions in a way to mitigate conflicts and maximize Satellite Contacts with respect to Facility Antennas availability.

5.1.1 Initialization of the System

[ARS020] Composition of the System Configuration: The ARS shall have a user-configurable System Configuration that includes:

- List of Missions with associated relative priority,
- List of Facilities with associated relative priority,
- Scheduling window start time and duration,
- Contingency Contact identification time window (as per [ARS153]),
- External Facility confirmation timeout (as per [ARS380]),
- Automatic scheduling enables [fixed-time daily, upon contact request, upon unavailability report], (as per [ARS100]), and
- User-selectable optimization cost function and weightings (as per [ARS120]).

[ARS030] Composition of the Facility Configuration: The ARS shall have one user-configurable Facility Configuration per schedulable Antenna resource that includes:

- Facility name,
- Antenna identifier,
- Antenna geographical location coordinates (longitude, latitude, altitude),
- Supported frequency bands [S, X, C, …],
- Supported service [Ranging (RNG), Telecommanding (TC), Real-time telemetry (RT-TM), store & forward telemetry (SF-TM), Real-time data reception (RT-DR), store & forward data reception (SF-DR)],
- Pre-pass setup time,
- Post-pass closeout time,
- Minimum valid RF contact duration,
- Systematic/recurring unavailability constraint,
- Transmission elevation mask,
- Reception elevation mask, and

- Key-hole.

[ARS040] Composition of the Mission Configuration: The ARS shall have one user-configurable Mission Configuration per Satellite that includes:

- Mission name,
- Spacecraft identifier and catalogue number,
- Scheduling mode [by Satellite Contact Request, by Configuration Requirements],
- List of qualified Facility Antennas,
- Daily operational time window (real-time pass activities), where applicable,
- Mission replanning lead time (used for automatic contact (re-)scheduling),
- Scalable set of Contact Types (used for automatic contact (re-)scheduling):
  - Contact Type name and identifier,
  - Spacecraft valid operational mode for Type [NOMINAL, LEOP, EMERGENCY, PROFICIENCY],
  - Autonomous scheduling Constraints:
    - Contact Type Criticality [ROUTINE, IMPORTANT, CRITICAL],
    - Contact RF bands [S, X, C, …],
    - Contact required services [RNG, TC, RT-TM, SF-TM, RT-DR, SF-DR],
    - Minimum antenna elevation,
    - Minimum RF contact duration,
  - Autonomous scheduling Requirements:
    - Minimum number of contacts per day,
    - Minimum and maximum gap between contacts,
    - Minimum total daily contact time.

5.1.2 Operational Sequence Event 1

[ARS050] Schedule computation inputs: The ARS shall compute a Schedule based on:

- Antenna Unavailability Reports provided by Facilities, and
- Satellite Contact Requests when provided by Missions, or
- Mission Configuration Requirements otherwise (as per [ARS040]).

[ARS060] Update of Satellite Orbital Ephemeris: The ARS shall keep Satellite Orbital Ephemeris up to date by receiving it from Missions and by automatically

retrieving it daily from online satellite catalogues (space-track.org, celestrak.com).

[ARS061] Default Satellite Orbital Ephemeris: The ARS shall default to the online satellite catalogue data update only if the Mission did not provide updated Satellite Orbital Ephemeris for a determinate time.

5.1.3 Operational Sequence Event 3

[ARS070] Orbit propagation and Satellite Contacts prediction: The ARS shall automatically propagate Satellite Orbital Ephemeris and generate the Compliant Satellite Contact List within the configured Scheduler time window base on both Mission and Facility Configuration Constraints, as well as the Antenna Unavailability Reports.

[ARS071] Contact prediction constraints: Mission and Facility Constraints used in Contacts prediction shall be user-configurable and include:

- Mission qualification/compliance with Facility,
- Frequency bands,
- Services (Ranging (RNG), Telecommanding (TC), Telemetry (TM), Data Reception (DR)),
- Time (setup time, minimum contact time, maximum gap between contacts, etc.),
- Geographic location, and
- Minimum elevation and specific Antenna horizon masks.

Note: Refer to [ARS050] and [ARS060] respectively for specific Facility and Mission Configuration definition requirements.

5.1.4 Operational Sequence Event 4

[ARS080] Validation of a Satellite Contact Request: The ARS shall validate Satellite Contact Requests against the Compliant Satellite Contact List and generate a Satellite Contact Request Validity Report.

[ARS090] Satellite Contact Request Validity Report: The Satellite Contact Request Validity Report shall contain the Request information plus an programmable invalidity qualifier field (e.g. antenna unavailable, wrong antenna, wrong frequency band, wrong service, wrong time, etc. (as per [ARS422])).

Note: Validity Report will be used to produce the Satellite Contact Request Acknowledgment (as per [ARS420]).

5.1.5 Operational Sequence Event 6

[ARS100] Automation of the Schedule computation: The ARS shall compute the Schedule automatically depending on a user-defined System Configuration,

- at a fixed-time fixed-interval,
- every time a new Satellite Contact Request is received, and
- every time a new Antenna Unavailability Report is received.

[ARS110] Schedule de-conflicting rules: The ARS shall compute a Schedule based on a set of user-configurable hard rules not limited to:

- A Critical Contact from a low priority Mission always overrule a Routine Contact from a higher priority Mission.
- A Committed Critical Contact may not be overruled except by the Operator.

Note: As per Definitions (Section 2.2), fast-tasking Contacts will be requested as IMPORTANT, and spacecraft emergency will be requested as CRITICAL.

[ARS120] Schedule optimization factors: The ARS shall de-conflict the Compliant Satellite Contact List and compute a Schedule by optimizing a user-configurable weighted cost function based, on:

- Satellite Contact Requests fulfillment,
- Mission Configuration Requirements:
  - required number of daily Contacts,
  - required total daily contact time,
- System Configuration priority factors:
  - Mission priority,
  - Facility preference,
  - Contact Criticality,
- Schedule performance factors:
  - total number of Satellite Contacts,
  - total Contact time duration, and
  - Antenna access cost.

Note: It is assumed that the optimization cost function is a linear equation made from the combination of one or more of the optimization factors and their respective user-configurable weighting parameters.

Note: Mission priorities are decided in agreement by a board of Mission Managers.

[ARS130] Rescheduling of overruled Committed Satellite Contacts: The ARS shall automatically reschedule an overruled Committed Satellite Contact from the Compliant Satellite Contact List and in accordance with the value of the Contact Request reschedulability field (when provided on Satellite Contact Request (defined in [ARS412])).

[ARS131] Contact Request Reschedulability Field: The Contact Request reschedulability field shall specify to:

- Drop the requested Contact completely, or
- Reschedule within a validity time window (e.g. opportunity window for fast-tasking requests), or
- Reschedule at best (no time window).

[ARS140] Tracking of Schedule changes: The ARS shall keep track of what Contacts are added and deleted from a previous Schedule applicable to the same time window.

[ARS141] Contact Update Field: The Schedule shall contain a separate Contact Update field to indicate whether the specific Contact is NEW or REMOVED from the previous Schedule.

Note: Tracking of added/removed Contacts between Schedule iterations should be independent of the Contact Request Status field on a given Schedule (as per [ARS431]).

[ARS150] Critical Contact contingency: For each scheduled Critical Contact, the ARS should identify a Contingency Contact on another Facility Antenna.

[ARS151] Contingency Contact identification process: The Contingency Contact identification process shall leave the Antenna resource unreserved and available to the System for normal de-conflicting and computing of the Schedule.

[ARS152] Contingency Contact labeling: The Contingency Contact shall be shown on the Schedule as Contingency Contact.

Note: the Contingency Contact will also show on the Antenna Reservation Request, but not necessarily de-conflicted from non-Critical Contacts.

[ARS153] Contingency Contact time window: The Contingency Contact shall be within a user-configurable time after beginning of the scheduled Critical Contact.

5.2 OPERATIONAL REQUIREMENTS

5.2.1 Operational Sequence Event 1

[ARS200] Notification of Reception: The ARS shall notify the Operator when a Satellite Contact Request or Antenna Unavailability Report is received.

5.2.2 Operational Sequence Event 2

[ARS210] Approval of Satellite Contact Request: The ARS shall have a functionality for the Operator to individually approve, remove or add Contacts and reattribute Contact Criticality on Satellite Contact Requests.

Note: The Mission is informed of any changes made by the Operator through the Committed Satellite Contact Schedule (defined in [ARS431]).

[ARS220] Manual entry of Satellite Orbital Ephemeris: The ARS shall have a functionality for the Operator to manually enter or edit the Satellite Orbital Ephemeris.

5.2.3 Operational Sequence Event 5

[ARS230] Manual reservation of Satellite Contacts: The ARS shall have a functionality for the Operator to manually reserve Contacts on the Compliant Satellite Contact List before the computation of a Schedule.

[ARS231] Manual reservation priority: The manual reservation mechanism shall come before and have superseding rights over any priority decision making of the optimizer during the computation of a Schedule.

5.2.4 Operational Sequence Event 6

[ARS240] Manual override of automatic Schedule computation: The ARS shall have a functionality for the Operator to override the automatic computation of a Schedule, and manually start and abort its computation at any time.

5.2.5 Operational Sequence Event 7 and Event 10

[ARS250] Approval of Preliminary and Accepted Schedules: The ARS shall submit Preliminary and Accepted Schedule to the Operator for approval/commitment before promoting the Schedule from Preliminary to Approved state and from Accepted to Committed state.

Note: As per Definitions (Section 2.2), Accepted Schedule relates to the acceptance of an Antenna Access Request by the Facility from ARS and the Operator has to commit the Schedule after confirmation of the Request from the Facility.

[ARS251] Backlog of previous Committed Schedules: The previous Committed Schedule shall become Obsolete but remain accessible and manageable by the Operator at any later time.

Note: It is not expected that the backlog of previous Schedule be an issue on the ARS storage capacity, and it is expected that the Operator can clean up the backlog as needed.

[ARS252] Restoring of backlog Schedule: The ARS shall have a functionality for the Operator to re-commit a previous Schedule that was declared Obsolete.

Note: This reverse functionality will be used to recover from any operational mistake happening during the approval process of a Schedule.

[ARS260] Locking of Committed Contacts: The ARS shall have a functionality for the Operator to individually lock Committed Contacts on a Schedule to prevent any future automatic rescheduling process from overruling the Locked Contact.

[ARS261] Notification of Conflict with Locked Contacts: The ARS shall issue a warning to the Operator when a new Antenna Availability Report gets in conflict with a Committed Contact that was previously locked by the Operator.

[ARS270] Automatic override of Operator's approval processes: The ARS shall have provision for bypassing the Operator's approval processes in accordance to a user-configurable System parameter and with different levels of autonomy:

- Always bypass Operator's approval,
- Bypass only when there is no conflicts,
- Bypass only during off hours, or
- Never bypass.

Note: It is assumed that this Operator bypass functionality will only be used when the stability of the scheduling is understood and fully controlled, and when there is a need for emergency or fast-tasking request in the absence of an Operator to approve the Schedule. Usage of this functionality will have to go through performance review and risk analysis.

5.2.6 Operational Sequence Event 8

[ARS280] Generation of Approved Schedule derived products: The ARS shall generate from the Approved Schedule one Antenna Schedule per External Facility (for the Antenna Reservation Request).

5.2.7 Operational Sequence Event 11

[ARS290] Generation of Committed Schedule derived products: The ARS shall generate from the Committed Schedule one Antenna Schedule per Internal Facility and one Satellite Contact Schedule per Mission.

5.2.8 Operational Sequence Event 13

[ARS300] Schedule optimizer Performance Report: The ARS shall produce a Schedule optimizer Performance Report to the Operator that includes:

- Request fulfillment score indicating the number and proportion of Satellite Contacts allocated as per Request for each Mission,
- Requirement fulfillment score indicating the number of contacts and total contact time allocated as per Mission Configuration Requirement,
- Antenna total time usage and relative usage allocated to each Mission Satellite,
- Satellite total Contact time and relative Contact time allocated at each Facility Antenna,
- Number and proportion of mitigated and unresolved conflicts per Mission and total, and
- Per Mission and total Antenna access cost per day, and cumulative for the entire Schedule time window.

[ARS310] Antenna Reservation Performance Report: The ARS shall produce an Antenna Reservation Performance Report for each Internal Facility including:

- Antenna total time usage and relative usage allocated to each Mission Satellite, and
- Available unallocated Antenna time.

[ARS320] Satellite Contact Performance Report: The ARS shall produce a Satellite Contact Performance Report for each Mission including:

- Satellite total Contact time and relative Contact time allocated at each Facility Antenna,
- Request fulfillment score indicating the number and proportion of Satellite Contacts allocated as per Request, and
- Number and proportion of Committed, Rejected, Cancelled and Rescheduled Contacts.

5.3 PERFORMANCE REQUIREMENTS

[ARS350] Scalability: The ARS shall be scalable to accommodate a variable number of Facility and Mission Configurations.

Note: it is expected that the number of Facilities and Missions can go as high as 20 each.

[ARS360] Orbit propagation computation time: The ARS shall propagate Satellite Orbital Ephemera and generate the Compliant Satellite Contact List in less than one (1) minute when up to 10 Mission Satellites and up to 10 Facility Antennas are used.

[ARS370] Schedule computation time: The ARS shall compute an optimal Preliminary Schedule solution in less than five (5) minutes (TBC) when up to 10 Mission Satellites and up to 10 Facility Antennas are used.

Note: As per Definitions (Section 2.2), it is assumed that Network Stations are not considered schedulable Facilities and are outside the scope of ARS.

[ARS380] Antenna Access Request timeout: In the event that the ARS did not receive the Antenna Access Request Confirmation from the External Facility within a user-configurable time, the ARS shall consider the requested Contacts as Refused by the External Facility.

[ARS390] Satellite Contact Request overall processing time: With the exception of the Operator's interventions, the ARS shall process a Satellite Contact Request, compute and return a Satellite Schedule to the Mission in less than ten (10) minutes (TBC).

Note: This requirement represents the end-to-end time to process a request from the Mission and return a Schedule. It includes the time to propagate the orbits (as per [ARS360] and, to compute the optimal Schedule solution (as per [ARS370]). It also includes provision time for the various ARS communication handling with the Missions and with the Facilities.

Note: It is assumed that External Facilities will reply to an Antenna Access Request in less than 5 minutes.

5.4 INTERFACE REQUIREMENTS

5.4.1 Interface with Missions

[ARS400] Reception of Satellite Orbital Ephemeris: The ARS shall be capable of receiving and processing, at least twice per day, the Satellite Orbital Ephemeris from the Missions.

[ARS401] Configurable Satellite Orbital Ephemeris: The specific Satellite Orbital Ephemeris format shall be user-configurable through a description file for each Mission.

[ARS410] Reception of Satellite Contact Request: The ARS shall be capable of receiving and processing Satellite Contact Requests from respective Missions (which includes new submission, update and cancellation of a Request).

[ARS411] Configurable Satellite Contact Request: The specific Satellite Contact Requests format shall be user-configurable through a description file for each Mission.

[ARS412] Satellite Contact Request fields: The specific Satellite Contact Requests format shall support a scalable number of fields including:

- Request message generation date and time,

- Applicable time window,
- Mission/Satellite Identifier,
- Facility/Antenna Identifier,
- Contact Identifier,
- Contact Request Action [ADD, DELETE],
- Contact AOS and LOS times,
- Contact RF ON/OFF times,
- Contact RF bands [S, X, C, …],
- Contact required services [RNG, TC, RT-TM, SF-TM, RT-DR, SF-DR],
- Contact Criticality [ROUTINE, IMPORTANT, CRITICAL], and
- Contact reschedulability [DROP, RESCHEDULE, <time window>].

Note: Modification of a Contact on a Request will be handled through the Request Action by Deletion of the Contact and the Addition of a new Contact replacing the former one. The new contact will have a new Contact Identifier.

[ARS420] Acknowledgment of Satellite Contact Request: The ARS shall automatically send a Satellite Contact Request Acknowledgment to the respective Mission within one (1) minute after reception of a Request.

[ARS421] Configurable Satellite Contact Requests Acknowledgment: The specific Satellite Contact Request Acknowledgment format shall be user-configurable through a description file for each Mission.

[ARS422] Satellite Contact Requests Acknowledgment fields: The Satellite Contact Request Acknowledgment specific format shall support a scalable number of fields including:

- All fields from the Satellite Contact Request,
- Contact Request Status [DELETED, PENDING, REJECTED], and
- Contact Rejected Reason [OVERRULED, INCOMPLIANT ANTENNA, WRONG RF BAND, WRONG SERVICE, WRONG TIME].

Note: For some missions, the Acknowledgement will translate simply in a Request Validity Report.

Note: This requirement is only a message acknowledgement. Status COMMITTED will only come with the Committed Schedule (as per [ARS430]) after the Operator has approved the replied Schedule from External Facilities.

[ARS430] Transmission of Committed Satellite Contact Schedule: The ARS shall send Committed Satellite Contact Schedules to the respective Missions.

[ARS431] Configurable Satellite Contact Schedule: The specific Satellite Contact Schedule format shall be user-configurable through a description file for each Mission.
[ARS432] Satellite Contact Schedule fields: The specific Satellite Contact Schedule format shall support a scalable number of fields including:

- Originator and recipient,
- Request message generation date and time,
- Applicable time window,
- Mission/Satellite Identifier,
- Facility/Antenna Identifier,
- Contact Identifier,
- Contact AOS and LOS times, and
- Contact Request Status [DELETED, COMMITTED, REJECTED, CANCELLED, RESCHEDULED].

[ARS440] Reception of Satellite Contact Schedule Acknowledgment: The ARS shall manage Satellite Contact Schedule Acknowledgments from the Missions.

[ARS450] Communication scheme with the Mission: All transactions between the ARS and the Missions shall use a dropbox scheme where files are pushed from the originator to the client system.

[ARS460] Communication format with the Mission: All transactions between the ARS and the Missions shall be based on XML.

[ARS461] Format conversion of Mission messages: The ARS shall convert any inbound transaction from Missions into the XML format as required, and convert any outbound transaction to a format compatible with the Missions.

5.4.2 Mission-specific requirements

[ARS470] Interface with RCM: The ARS shall interface with the Mission Planning Subsystem of RCM (RD-1).

Note: It is assumed that RCM will be flexible to accommodate the ARS interface (AD-1).

[ARS471] Interface with Scisat: The ARS shall interface with the Mission Planning Subsystem of Scisat.

Note: It is assumed that Scisat will conform to the interface provided by the ARS (AD-1).

[ARS472] Interface with NEOSSat: The ARS shall interface with the Mission Planning Subsystem of NEOSSat.

Note: It is assumed that NEOSSat will conform to the interface provided by the ARS (AD-1).

[ARS473] Interface with M3MSat: The ARS shall interface with the Mission Planning Subsystem of M3MSat.

Note: It is assumed that M3MSat will conform to the interface provided by the ARS (AD-1).

5.4.3 Interface with Facilities

[ARS500] Reception of Antenna Unavailability Report: The ARS shall be capable of receiving and processing Antenna Unavailability Reports from Facilities.

[ARS501] Configurable Antenna Unavailability Report: The specific Antenna Unavailability Report format shall be user-configurable through a description file for each Facility.

[ARS502] Compatible Antenna Unavailability Report: The specific Antenna Unavailability Report format shall be compatible with AD-4.

[ARS510] Transmission of Antenna Access Request: The ARS shall send Approved Schedules as Antenna Access Requests to External Facilities.

[ARS511] Configurable Antenna Access Request: The specific Antenna Access Request format shall be user-configurable through a description file for each Facility.

[ARS512] Antenna Access Request fields: The specific Antenna Access Request format shall support a scalable number of fields including:

- Originator and recipient,
- Request message generation date and time,
- Applicable time window,
- Mission/Satellite Identifier,
- Facility/Antenna Identifier,
- Contact Identifier,
- Contact Request Action [ADD, DELETE],
- Contact AOS and LOS times,
- Contact RF ON/OFF times,
- Contact RF bands [S, X, C],
- Contact required services [RNG, TC, RT-TM, SF-TM, RT-DR, SF-DR], and
- Uplink required [YES, NO].

Note: It is assumed that the External Facilities will keep track of all Contacts that were requested by handling the Contact Request Action field from subsequent Antenna Access Requests.

Note: A subsequent Request will not edit a Contact definition. Modification of a Contact on a Request will be handled through the Request Action by Deletion of the Contact and the Addition of a new Contact replacing the former one. The new contact will have a new Contact Identifier.

[ARS513] Compatible Antenna Access Request: The Antenna Access Request format shall be compatible with AD-3.

[ARS520] Reception of Antenna Access Request Acknowledgment: The ARS shall manage Antenna Access Request Acknowledgments from Facilities.

[ARS521] Configurable Antenna Access Request Acknowledgment: The specific Antenna Access Request Acknowledgment format shall be user-configurable through a description file for each Facility.

[ARS522] Compatible Antenna Access Request Acknowledgment: The specific Antenna Access Request Acknowledgment format shall be compatible with AD-3.

[ARS530] Reception of Antenna Access Request Confirmation: The ARS shall manage Antenna Access Request Confirmations from Facilities.

[ARS531] Configurable Antenna Access Request Confirmation: The specific Antenna Access Request Confirmation format shall be user-configurable through a description file for each Facility.

[ARS532] Antenna Access Request Confirmation fields: The specific Antenna Access Request Confirmation format shall support a scalable number of fields:

- All fields from the Antenna Access Request,
- Contact Request Status [ACCEPTED, REJECTED, CANCELLED], and
- Rejected or Cancelled Reason [UNAVAILABLE, WRONG RF BAND, WRONG SERVICE, WRONG TIME].

Note: It is not expected that Facilities will reply with status RESCHEDULED as rescheduling is the task of the ARS.

[ARS533] Compatible Antenna Access Request Confirmation: The specific Antenna Access Request Confirmation format shall be compatible with AD-3.

[ARS540] Transmission of Committed Antenna Schedule: The ARS shall send Committed Antenna Schedules to Internal Facilities.

[ARS541] Configurable Committed Antenna Schedule: The specific Committed Antenna Schedule format shall be user-configurable through a description file for each Facility.

[ARS542] Committed Antenna Schedule fields: The specific Committed Antenna Schedule format shall support a scalable number of fields including:

- Originator and recipient,
- Request message generation date and time,
- Applicable time window,
- Mission/Satellite Identifier,
- Facility/Antenna Identifier,
- Contact AOS and LOS times,
- Contact RF ON/OFF times,
- Contact RF bands [S, X, C], and
- Contact required services [RNG, TC, RT-TM, SF-TM, RT-DR, SF-DR].

[ARS550] Communication format with the Facilities: All transactions between the ARS and the Facilities shall be based on XML.

[ARS551] Format conversion of Facility messages: The ARS shall convert any inbound transaction from Facilities into the XML format as required, and convert any outbound transaction to a format compatible with the Facilities.

5.4.4 Facility-specific requirements

[ARS560] Interface with SHUB and SASK: The ARS shall interface with the St-Hubert (SHUB) and Saskatoon (SASK) TT&C Facilities used for Scisat.

Note: It is assumed that SHUB and SASK will conform to the interface provided by the ARS (AD-1).

[ARS561] Interface with CCMEO SXGT: The ARS shall interface with the CCMEO SXGT Facilities.

Note: It is assumed that CCMEO Facilities will conform to the interface provided by the ARS (AD-1) and as per RCM assumptions and current design.

[ARS562] Interface with PE2: The ARS shall interface with the PE2 Reception Facilities used for RCM.

Note: It is assumed that PE2 will conform to the interface provided by the ARS (AD-1) and as per RCM assumptions and current design.

[ARS563] Interface with NGT: The ARS shall interface with the Northern Ground Terminal (NGT) Facilities used for RCM.

Note: It is assumed that NGT will conform to the interface provided by the ARS (AD-1) and as per RCM assumptions and current design.

5.4.5 Internal Interfaces

[ARS580] Interface with Live Schedule Board: The ARS shall interface with the CSA operational Live Schedule Board (AD-5).

Note: It is assumed that the Live Schedule Board interface will conform to the ARS.

5.5 QUALITY FACTORS

5.6 SECURITY REQUIREMENTS

[ARS600] System security: The ARS shall have control mechanisms to prevent unauthorized personnel to access or temper the System and its data.

Note: It is assumed that the security level of the System will not require security measures above PROTECTED B.

5.7 DESIGN AND CONSTRUCTION REQUIREMENTS

[ARS700] Operational backup capability: The ARS shall have a manual fail over Backup System capability to retain availability of all System's functionalities in case of Primary System failure.

Note: It is assumed that the Backup System will be a copy of the Primary System.

[ARS701] System failure detection: The failure detection and manual handover to the Backup System shall take less than 5 minutes.

[ARS702] Data persistency and accessibility in case of System failure: The current Configurations, previous Committed Schedules, Satellite Contact Requests and Antenna Unavailability Reports shall be accessible to the Backup System in case of Primary System failure.

[ARS710] Deployability: The ARS Primary System shall hold and operate with all its dependable libraries and third-part software on a single desktop computer system.

[ARS720] Portability: The ARS shall be portable from one computer system to another while keeping its integrity and functionality.

[ARS730] Availability: Including the backup capability, the ARS shall have an availability of 99.7% over the expected lifetime of the System (equivalent downtime of 1 day on average per year).

[ARS740] Lifetime: The ARS shall be designed for an expected operational lifetime of 20 years.

[ARS750] Accessibility of Data: The ARS shall store Configurations and Schedules in user-readable files on the System.

[ARS760] Backlog of Data: The ARS shall keep a history of all Configuration and Schedule files on the System.

[ARS770] Display of Schedule for the Operator: The ARS shall have an interactive Graphic User Interface (GUI) to display the Preliminary or Committed Schedule on a dynamic time-scale graph.

[ARS771] Flexibility of the Schedule view: The GUI shall allow the Operator to select which Mission/Satellite(s) or Facility/Antenna(s) to be displayed on the active Schedule view.

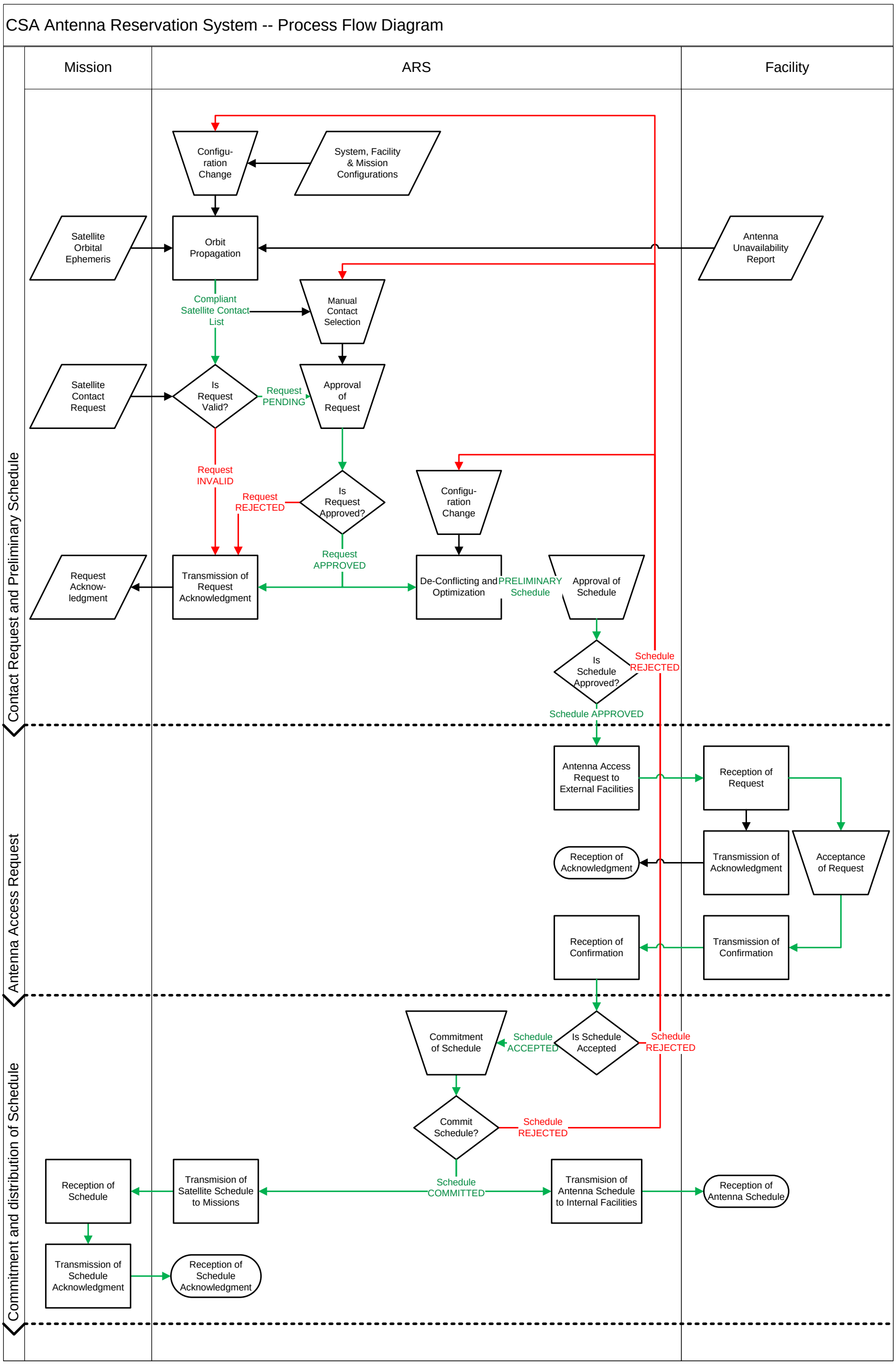
[ARS772] Printability of the Schedule view: The GUI shall allow the Operator to print the active Schedule view.

5.8 QUALIFICATION AND VERIFICATION REQUIREMENTS

[ARS800] System validation: The ARS shall be validated as a replacement to the CSA De-Conflict System (DCS) (RD-7).

APPENDICES

A PROCESS FLOW DIAGRAM



B COMPLIANCE MATRIX WITH RCM

TBC