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FINAL PRESENTATION

OF

STUDY ON ENHANCEMENT OF INTERNATIONAL INTEROPERABILITY

WP 1000 (MISSIONS AND INTEROP SCENARIOS)

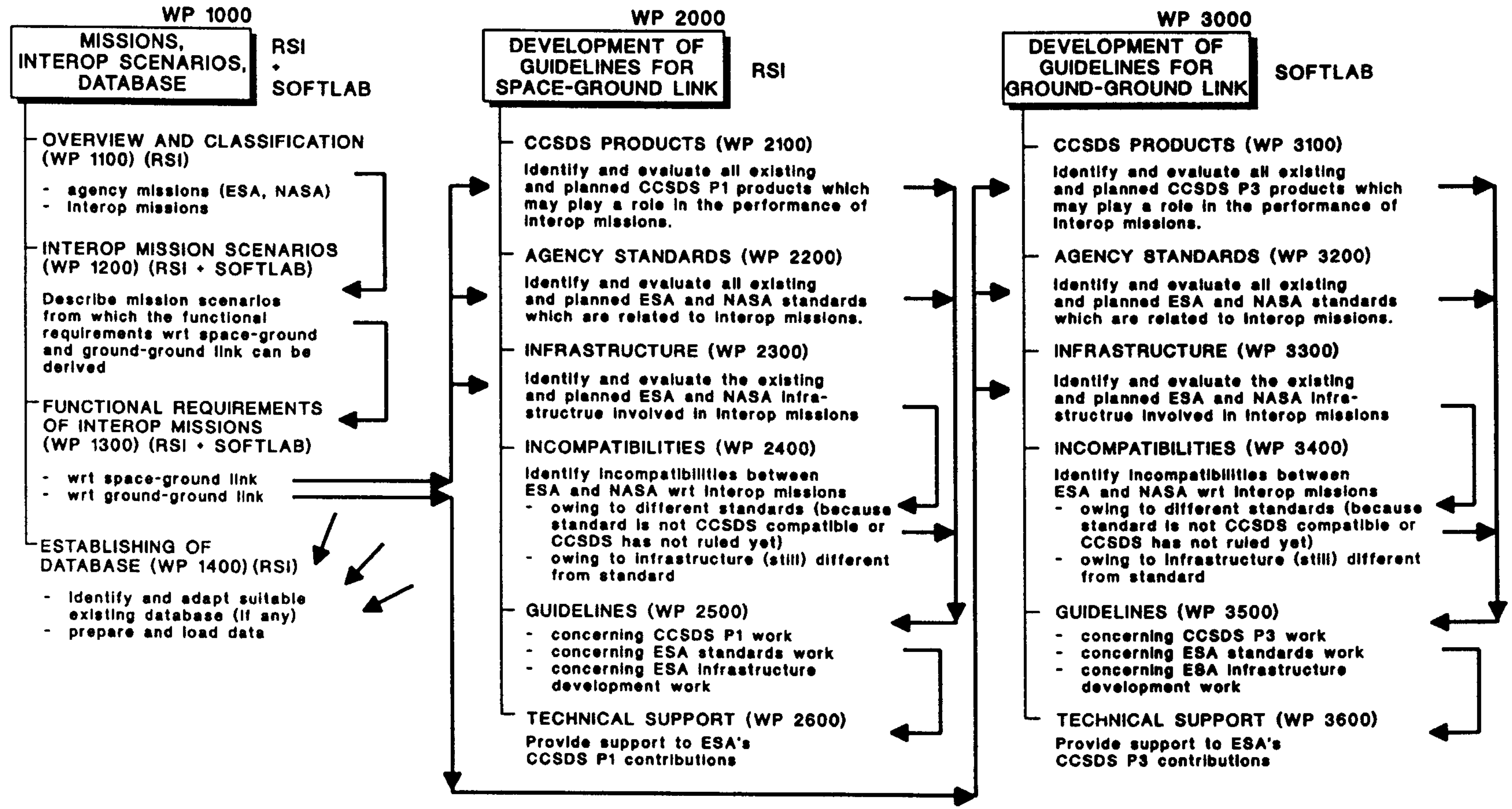
AND

WP 2000 (DEVELOPMENT OF GUIDELINES FOR THE SPACE-GROUND LINK)

by

H. Kummer

at ESOC on February 16th 1996



STUDY ON ENHANCEMENT OF INTEROPERABILITY
WORK BREAKDOWN STRUCTURE, LOGICAL FLOW AND ASSIGNMENT OF TASKS

TASKS OF WP 1000: MISSIONS, INTEROP SCENARIOS, DATABASE

WP 1100: OVERVIEW AND CLASSIFICATION OF MISSIONS

- ESA Missions
- NASA Missions
- Extraction of Interop Missions

WP 1200: INTEROP MISSION SCENARIOS

- Description of Interop Scenarios

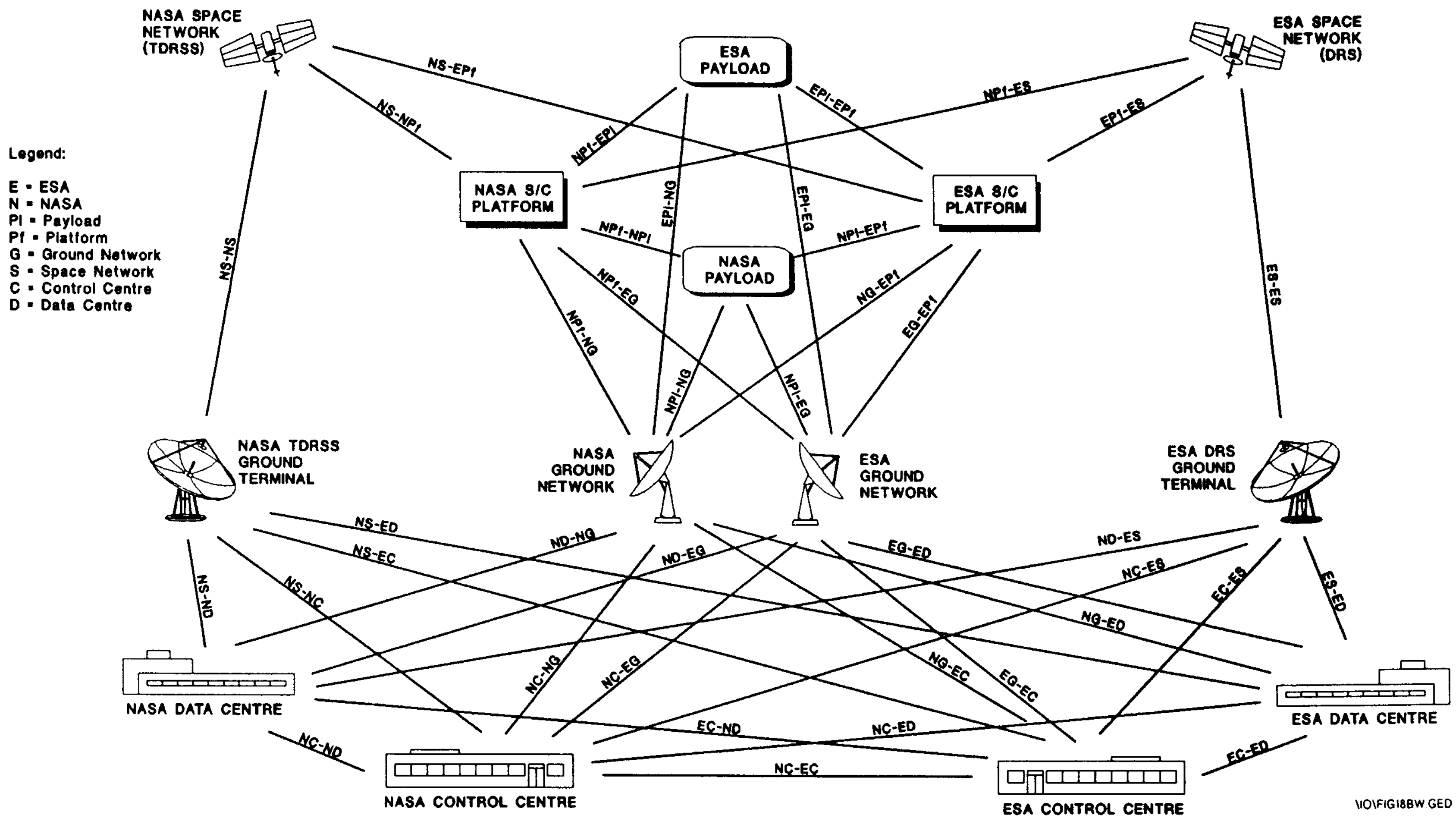
WP 1300: FUNCTIONAL REQUIREMENTS OF INTEROP MISSIONS

- With respect to Space-Ground Link
- With respect to Ground-Ground Link

WP 1400: ESTABLISHING OF DATABASE

- Identify and adapt suitable existing Database
- Prepare and load Data

ELEMENTS OF MISSION OPERATION SCENARIOS



ESA MISSIONS (Tables 2.1 and 2.2 in the Report) and NASA MISSIONS (Tables 2.3 and 2.4) (WP 1100)

WITH THE FOLLOWING COLUMNS:

- NO
- CATEGORY (Space Science Mission, Earth Observation Mission, Telecommunication Mission, Space Transportation Mission, unmanned and manned)
- NAME
- OBJECTIVES
- PAYLOAD/FUNCTIONS
- ORBIT
- SPACE-GROUND LINK TERMINALS/SYSTEMS (for platform, for payload)
- CONTROL CENTRES (for platform, for payload)
- SCIENCE OR DATA CENTRES
- OPERATION SCENARIOS; expressed in terms of links defined in the figure on page 4; the links representing interop scenarios have been underlined

INTEROP MISSION SCENARIOS (Table 3.1 of Report) (WP 1200)

CONTAINS INTEROP MISSION ONLY, WITH THE FOLLOWING COLUMNS:

- NO
- NAME (of mission)
- SERVICE REQUIREMENTS CONCERNING THE SPACE-GROUND LINK (describes those links which connect "nodes" belonging to different agencies)
- SERVICE REQUIREMENTS CONCERNING THE GROUND-GROUND LINK (describes those links which connect "nodes" belonging to different agencies).

STANDARD OPERATION SCENARIOS (Chapter 3 of Report) (WP 1200)

FOR THE SPACE-GROUND LINK:

(1) The EPf&PI-NG-EC Scenario (CLUSTER (b) and (d), COBRAS/SAMBA, ERS 1/2 (a), ENVISAT (a), HUYGENS (b), INTEGRAL, INTERMARSNET, ISO, METOP (a), MORO, ROSETTA)
(2) The EPf&PI-NG-NC Scenario (ULYSSES, SOHO (a), STEP (option 1), METEOSAT and METEOSAT SG when operated by NOAA (such as lease arrangements as currently for one METEOSAT satellite))
(3) The EPI-NG-ND Scenario (ERS 1/2 (e), METOP (e), ENVISAT (e))
(4) The NPI-EG-ED Scenario (EOS (d), Landsat 7 (c) and NOAA-K, ..., -Q (b))
(5) The ARIANE Scenario
(6) The SPACE STATION Scenario
(7) SPACELAB & EURECA Scenario
(8) Payload-Platform Interface Scenario (ESA payload on NASA platform: HUBBLE, FAST (c), EOS (e), (g), and (f); also SPACE STATION and SPACELAB; NASA payload on ESA platform: CLUSTER (f), METOP (f), SOHO (b), STEP (b))
(9) Proximity Operations Scenario (ATV (c) and CTV (c)).

FOR THE GROUND-GROUND LINK

(1) The NG-EC Scenario (CLUSTER (b) and (d), COBRAS/SAMBA, ERS 1/2 (a), ENVISAT (a), HUYGENS (b), INTEGRAL, INTERMARSNET, ISO, METOP (a), MORO, ROSETTA)
(2) The EG-NC Scenario (potential emergency operations situations)
(3) The NC/D-EC/D Scenario (COLUMBUS (c) and SPACE STATION (c), EURECA (a), SOHO (c), SPACELAB Missions, EOS (f), FAST, ATV, CTV)

FUNCTIONAL REQUIREMENTS OF INTEROP MISSIONS (Chapter 4 of Report) (WP 1300)

FOR THE SPACE-GROUND LINK:

- Contains the requirements of the standard interop scenarios in terms of the services currently discussed by CCSDS.
- Defines these services for Conventional Telemetry (Table 4.1 of Report), for Telecommand (Table 4.2) and for the AOS Space Link Subnet (Figure 4.1).
- Checks through the 9 standard operations scenarios and identifies the services required (which have been defined before) as follows:

(1) The EPf&PI-NG-EC Scenario

- Return Link (Telemetry)

Layer E: Space Mission Application Layer: With respect to the interface EPf&PI-NG the Layer E services will not play any role because it can be assumed that the various sources deliver their data in form of Source Packets and/or Privately Defined Data and/or Frame Secondary Headers and/or Operational Control Fields. The latter will be addressed again when the requirements for the forward link (telecommand) will be discussed.

Layer D: Space Transfer Layer: The services T-D1 and T-D4 are essential. T-D1 for constructing the Frame Data Fields, the First Header Pointer and the flags. T-D4 is required for the transmission of the Command Link Control Word. Because of the variety of different missions quoted under ? it is assumed that the services T-D2 and T-D3 will be required as well. This will have to be investigated further in WP 2000.

Layer C: Virtual Channel Access Layer: All services T-C1 through T-C3 will be required as it is likely that several Virtual Channels will be needed for typical missions. Of course, T-C2 and T-D3 as well as T-C3 and T-D4 are mutually exclusive.

Layer B: Channel Access Layer: Both services T-B1 and T-B2 will be required where the three options of coding have to be available.

Layer A: Physical Access Layer: This service will be required.

Summary: All services listed in Table 4.1 except T-E1 through T-E3 will be required.

- Forward Link (Telecommand)

Layer B: Data Routing Layer: The services C-B1 and C-B2 are both essential. C-B1 for segmenting the packets into Frame Data Units in case they do not fit into the Frame Data Fields and C-B2 for encapsulating TC Frame Data Units into TC Transfer Frames and for implementing the Command Operation Procedure 1 (COP1).

Layer A: Channel Access and Physical Access Layer: Both the services C-A1 and C-A2 are essential. C-A1 for encoding the TC Transfer Frames into TC Codeblocks and encapsulating these into Command Link Transmission Units and C-A2 for operating the radio frequency path to the spacecraft.

(2) The EPf&PI-NG-NC Scenario

The service requirements concerning the space-ground link for both the return and the forward link are the same as for scenario (1).

(3) The EPI-NG-ND Scenario

There are requirements for the return link only, and these are the same as for the return link in scenario (1).

(4) The NPI-EG-ED Scenario

There are requirements for the return link only, and these are the same as for the return link in scenario (1).

(5) The ARIANE Scenario

For a CCSDS-compatible telemetry link in principle the return link services described for scenario (1) are required. However, in the ARIANE scenario a specific spacecraft is addressed. Thus, it may be possible to drop the one or the other service component in the Space Transfer Layer and reduce the requirements there, for example, to T-D3 (Virtual Channel Frame Secondary Header Service) only. It is also conceivable that transmission on one virtual channel only takes place which would somewhat effect the service T-C1.

(6) The Space Station Scenario

Three sub-scenarios are mentioned have been defined:

- the communication between COF and ISSA data handling systems
- the communication between the European payload and the NASA Lab data handling system
- the communication between the NASA payload in the COF with the COF data handling system

All three scenarios address on-board links. Because of voice and video requirements involved the AOS services are assumed, except for telecommanding.

- Return Link (Telemetry): The COF and ISSA data handling systems deliver CCSDS packets. The European payload in the US Lab and the US payload in the COF deliver CCSDS packets. All require the AOS Multiplexing service for further handling.

- Forward Link (Telecommand): Use of the "conventional" telecommand service as described for scenario (1) is required. It remains to be seen whether NASA will support any other than COP1, e.g. an AOS Grade 1 service based on ARQ procedures.

- Voice: The "European payload" delivers and receives octets or groups of octets using the AOS Insert Service or the Virtual Channel Access Service, depending on the particular application.

- Video: The "European payload" delivers and receives Fixed Length Data Units using the AOSD Virtual Channel Access Service or the Bitstream Service depending on the particular application.

(7) Spacelab & Eureca Scenario

The service requirements are the same as for the Space Station Scenario except that the platform handling the data services will be the Shuttle instead of the core space station. It is not expected, however, that anything will be changed in favour of CCSDS Recommendations at the Shuttle data handling system.

(8) Payload-Platform Interface Scenario

The difference between the Space Station, Spacelab & Eureca scenarios and the scenario for other missions shows that the latter do not need voice and video links.

For telemetry and telecommand the same services as identified for scenarios (1) will be required.

(9) Proximity Operations Scenario

For this scenario the services of a space-ground link as an analogon to the necessary space-space link have to be provided.

- Telemetry Link: The services described under ? are required. The conventional telemetry and the AOS services are essentially differing in the type of frame they are using. In view of voice and video transmissions it is likely that AOS services will be needed. Not all services of the Space Transfer Layer or corresponding AOS services may be required.

- Telecommand Link: Use of the "conventional" telecommand service as described in Section ? is required. It remains to be seen whether NASA will support any other than COP1, e.g. an AOS Grade 1 service based on ARQ procedures.

- Voice: The two way voice transmission takes place via isochronously released Octets exchanged by means of the AOS insert service or the Virtual Channel Access Service, depending on the particular application.

- Video: The two way video transmission takes place via Fixed Length Data Units using the AOS Virtual Channel Access Service or the Bitstream Service depending on the particular application.

TASKS OF WP 2000: DEVELOPMENT OF GUIDELINES FOR THE SPACE-GROUND LINK

WP 2100: OVERVIEW AND CLASSIFICATION OF MISSIONS

- Identification and evaluation of all existing and planned CCSDS P1 products which may play a role in interop missions

WP 2200: AGENCY STANDARDS (RELATED TO INTEROP MISSIONS)

- ESA
- NASA

WP 2300: AGENCY INFRASTRUCTURE (RELATED TO INTEROP MISSIONS)

- ESA
- NASA/GSFC
- NASA/JPL

TASKS OF WP 2000: DEVELOPMENT OF GUIDELINES FOR THE SPACE-GROUND LINK (cont.)

WP 2400: COMPATIBILITIES (RELATED TO INTEROP MISSIONS)

- Forward link
- Return link
- Ranging
- Other interfaces

WP 2500: GUIDELINES

- Concerning CCSDS activities
- Concerning ESA's standards activities
- Concerning the evolution of ESA infrastructure
- Other guidelines

WP 2100: CCSDS PRODUCTS RELATED TO INTEROP MISSIONS

(1) LINK BETWEEN AN ESA PLATFORM & PAYLOAD AND A NASA GROUND STATION OR FOR THE REVERSE LINK

- Link between ESA platform & payload and NASA ground network
- Link between ESA payload and NASA ground network
- Link between NASA payload and ESA ground network

RETURN LINK

- Recommendations on RF & modulation
- Recommendation on telemetry channel coding
- Recommendation on (conventional) packet telemetry
- Planned recommendation on (conventional) packet telemetry services
- Recommendation on advanced orbiting systems
- Recommendation on time code services

FORWARD LINK

- Recommendation on RF & modulation
- Telecommand recommendation, parts 1, 2, 2.1 and 3
- Recommendation on Advanced Orbiting Systems, <u>but ARQ procedure not worked out</u>

WP 2100: CCSDS PRODUCTS RELATED TO INTEROP MISSIONS (cont.)

(2) THE ARIANE SCENARIO

- PCM-like synchronous clocking out of telemetry through frame secondary header service

(3) THE SPACE STATION SCENARIO

- Return link through multiplexing service of AOS (payload-platform interface is still "local matter")
- Forward link through telecommand recommendations
- Voice and video through recommendation on audio, video and still-image communication services

(4) THE SPACELAB & EURECA SCENARIO

- Not considered for historical reasons

(5) THE PAYLOAD-PLATFORM INTERFACE SCENARIO

- As for space station scenario
- Application protocol defining interface between payload and onboard data handling system is not available

(6) THE PROXIMITY OPERATIONS SCENARIO

- No recommendations available

WP 2200: AGENCY STANDARDS RELATED TO INTEROP MISSIONS

(1) LINK BETWEEN AN ESA PLATFORM & PAYLOAD AND A NASA GROUND STATION OR FOR THE REVERSE LINK

- ESA:
  - RF & Modulation Standard fully compatible with CCSDS
  - Telemetry Channel Coding Standard fully compatible
  - Packet Telemetry Standard fully compatible (except space mission application layer service)
  - AOS; ESA is preparing standard, essentially copied from CCSDS
  - Packet Utilisation Standard is not (yet) CCSDS regulated
  - Telecommand Standard is fully compatible (except minor differences on "service cycle completion")
- NASA:
  - NASA standards have not been available to the study author
  - JPL seems to adopted CCSDS Recommendations by "title-page exchange"
  - In this situation it is proposed to consider NASA infrastructure directly (see below)

(2) THE ARIANE SCENARIO

- ESA:
  - Packet Telemetry Standard
- NASA:
  - see remarks under (1)

WP 2200: AGENCY STANDARDS RELATED TO INTEROP MISSIONS (cont.)

(3) THE SPACE STATION SCENARIO

- ESA:
  - develops AOS-compatible standard
  - possibly also voice, video and still image standard
  - incompatibilities due to missing standards not expected
- NASA:
  - see remarks under (1)

(4) THE SPACELAB & EURECA SCENARIO (not further treated for historical reasons)

(5) THE PAYLOAD-PLATFORM INTERFACE SCENARIO

- No standards available
- ESA has developed hardware which defines de facto the application protocol interface (not a standard)

(6) THE PROXIMITY OPERATIONS SCENARIO

- No specific standards available
- however, space-ground link standards could be used

WP 2300: AGENCY SPACE DATA INFRASTRUCTURE RELATED TO INTEROP MISSIONS

This WP evaluates the ESA and NASA infrastructure with respect to the interop missions.

(1) ESA

- Table 4.1: Overview of ESA Space Data Infrastructure
- Figure 4.1: ESA General Purpose Ground Station Block Diagram
- Table 4.2: Characteristics of ESA General Purpose Ground Stations
- Tables 4.3 and 4.4: Characteristics of ESA Mission dedicated Ground Stations 1 and 2
- "Post Mark III" systems:
  - an old technology frame processor exist and has been used for EURECA (can also do packet extraction)
  - current implementation is for CLUSTER and supports frame processing and (later) packet extraction (according to Packet Telemetry Standard)
  - two new technology frame processors are planned, the TMP (Telemetry Processor) for mission dedicated stations (up to 300 Kbps) and the RPHS (Return Link Protocol Handling System) for LEOP stations (up to 4 Mbps)
  - AOS frame processor will also be available
  - telecommand systems (still on Mark II standard) will eventually be upgraded to new ESA standard
  - CDS2, the decoding system will support CCSDS and more (currently planned speed 4 Mbps)

(2) NASA

- Table 4.6: Overview of NASA Space Data System Facilities
- Table 4.7: Mission Assignment of NASA Space and Ground Network
- Figure 4.2: Hierarchy of NASA Space and Ground Networks

WP 2300: AGENCY SPACE DATA INFRASTRUCTURE RELATED TO INTEROP MISSIONS (cont.)

- DSN (based on References [3] and oral information):
  - Figure 4.3: Planned 1997 DSN Configuration
  - Table 4.8 and 4.9: Characteristics of NASA DSN 1 and 2
  - Figure 4.4: Functions of JPL Signal Processing Centres
  - Forward Link: DSN will provide packet telecommand capability following the applicable CCSDS recommendations (see references [5] through [8] and [21]) and is supporting COP-1. According to the text in [3] this capability has to be requested, however. New Command Processor Assemblies will be capable of handling rates from 1 b/s to 2 kb/s.
  - Return Link: S-band on 70m and 34m stations will be used for both Category A and B missions. All 70m and 34m stations will be able to receive X-band for Category A and Category B missions.

  The 11m stations will be able to receive high data rates (up to 150 Mbps). They do not possess sophisticated data processing equipment. Data are demodulated and recorded. The 11m stations are not connected to the SPCs.

  Ku-band reception will be for Category-A missions and Ka-band reception for Category-B missions.

  All RF services will be provided according to the CCSDS recommendations.

  As concerns the telemetry data services, these will support the CCSDS recommended coding (except the randomizer option) and packet telemetry data structures and services (except segmentation). It is apparently not supporting any AOS services. The data rates are limited to 2.2 Mbps, if higher rate convolutional codes are used, to 1.1 Mbps.

WP 2300: AGENCY SPACE DATA INFRASTRUCTURE RELATED TO INTEROP MISSIONS (cont.)

- **GSFC (based on References [1], [27], [30] and [31]):**
  - Table 4.10: NASA Ground Network (except DSN)
  - Digitised data are received from and transmitted to the Information Processing Division (IPD)
  - IPD will in future (except for old s/c) support only "frame and packet based technology as described in the CCSDS recommendations" (see [27], pages 3-10, 3-11)
  - The data processing services of IPD are (or will be) performed by Pacor II and EDOS
  - Pacor II: is a multi-satellite support system to capture and to provide level-zero processing of packet telemetry for spacecraft that adhere to the CCSDS recommendations (see [27], page 3-11), (missions: SOHO, XTE, ACE, SMEX); located at GSFC
  - EDOS: space data handling facility for EOS programme (services for return link processing, forward link processing, operations management, production data handling, data archiving, engineering support, system support), decentralised.

  EOS uses mainly TDRSS, thus functions of Data Interface Facility (DIF) at White Sands important (functions: data capture, return link processing, forward link processing, operations management, communication interface, system support)

WP 2300: AGENCY SPACE DATA INFRASTRUCTURE RELATED TO INTEROP MISSIONS (cont.)

(3) SPACE DATA SYSTEM GROUND FACILITIES USED FOR INTEROP SCENARIOS

- Table 4.11
- Conclusions

  - ESA will gradually upgrade its infrastructure according to newest ESA standards and thus compatible with CCSDS
  - The JPL Signal Processing Centres and the GSFC systems Pacor II and EDOS are projected and/or designed according to CCSDS (documents with details have just been received and will be taken into account for the completion of the Final Report)
  - Future NASA satellites will be CCSDS compatible
  - CLUSTER will use AOS frames but not packets; it will not use CCSDS on the uplink although interop mission (NDIUs will be used)
  - ENVISAT will not use CCSDS on S-band, but AOS frames and packets on X- and Ka-band
  - With respect to the earth observation satellites operated during the first 5 or 10 years of the next millennium we could then have a situation of almost maximum incompatibility:

    - For ENVISAT the S-band link will not be CCSDS-compatible, but the X-/Ka-band link will be.
    - For METOP currently (Phase B) both the S-band and the X-band plus Ka-band links are planned to be CCSDS-compatible, but changes may be made due to NOAA decisions.
    - For NOAA-O,-P,-Q neither the S-band nor the X-band link will be CCSDS-compatible.
    - For EOS all links on S-band, X-band and Ku-band will be CCSDS-compatible.
    - For Meteosat Second Generation both the S-band and the L-band link will be CCSDS-compatible (at least for the time being).

  No doubt, the trouble-makers are NOAA and some ENVISAT "existing platform fetishists". The author of this study believes that at least the NOAA decision could still be reverted, with some help from NASA.

WP 2400: COMPATIBILITIES

This WP describes the current and gives an outlook on the future situation.

Figure 5.1

(1) TELECOMMAND

- ESA: PCM Telecommand System
- NASA GSFC: "flexible" PCM telecommand system; no compatibility problems with ESA system
- NASA DSN: different from the GSFc system because of different requirements; no detailed information; degree of compatibility with ESA not known
- Incompatibilities: parameter adjustment between ESA and GSFC; some more adaptation work between ESA and DSN; better compatibility exists when services are adapted and communication interfaces are harmonised
- Future commanding of ESA satellites through NASA stations:
  - through Wallops and Poker Flat: ENVISAT, METOP
  - through DSN: COBRAS/SAMBA, INTEGRAL, INTERMARSNET, ISO, MERCURY ORBITER, MORO, ROSETTA, SOHO, STEP.
- There should be no compatibility problems in future (frequencies, polarisation, modulation, PDU's and services) because both agencies intend to upgrade in accordance with CCSDS

WP 2400: COMPATIBILITIES (cont.)

(2) TELEMETRY

- ESA: Mark I, II and III
- NASA GSFC: Pacor I (various types of TDM telemetry, mostly mission specific)
- NASA JPL: "Currently, the DSN telemetry system complies with the CCSDS recommendation for packet telemetry" (see [3], page 30); there is a question mark behind this.
- Incompatibilities: PCM (and some early packetised) telemetry is mission specific
- Future interop concerning telemetry:
  - Bermuda: ARIANE 5
  - Wallops, Poker Flat, possibly Santiago: ENVISAT (S-band), METOP (S-band)
  - NOAA Stations: ENVISAT (X-band), METOP (X-band), METEOSAT Second Generation (X-band)
  - DSN: COBRAS/SAMBA, INTEGRAL, INTERMARSNET, ISO, MORO, ROSETTA, SOHO, STEP
  - European earth observation data reception stations: EOS, LANDSAT 7
  - EUMETSAT stations: NOAA-O,-P,-Q.
- There should be no compatibility problems in future; watch the communications interface !

(3) RANGING

- spacecraft transponders are being used which are compatible with the ranging systems of both agencies

WP 2400: COMPATIBILITIES (cont.)

(4) OTHER INTERFACES

- Spacecraft to spacecraft communication (examples Spacelab, Eureca, ATV)
- On-board data interface between instruments and on-board data handling system

WP 2500: GUIDELINES

This WP contains recommendations, derived from the results of this study, concerning the activities of CCSDS and ESA.

(1) CCSDS ACTIVITIES

- **Lower and middle layer products**
  - Completion of Telemetry Services book
  - Harmonisation/combination of conventional and AOS telemetry recommendations and in this context the introduction of parameter driven PDUs
  - Modification/Adaptation of command PDUs and operation procedures

- **Upper layer services and protocols**
  - onboard data interfaces between instruments and platform data handling systems
  - services and protocols for proximity operations
  - The METOP/NOAA mission scenario.

- **General**
  - Quality of some older CCSDS documents should be improved

WP 2500: GUIDELINES (cont.)

(2) ESA ACTIVITIES

- Current pace in adapting CCSDS recommendations in ESA standards should be maintained
- Direct adaptation (copying) of CCSDS recommendations should be considered; Indication of options required
- Projects should be encouraged to use ESA standards and standard components

(3) OTHER GUIDELINES

- Cooperation between NASA and ESA at the design of space data systems
- Compatibility tests (Figure 6.1).

CONCLUSIONS COVERING WP's 1000 and 2000 (SPACE-GROUND LINK)

- The CCSDS activities have definitely led to a convergence of NASA and ESA space data infrastructure.
- Both agencies are in the process of updating their space data infrastructure in accordance with the recommendations of CCSDS.
- Owing to missing information on details it was not possible to prove "paper-based" compatibility, thus tests will be required (infrastructure-oriented, not project-oriented !).
- Save for some projects which are in the later stages of development and some earth observation satellites, all future NASA and ESA satellites are likely to be designed according to CCSDS recommendations.

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2.2 ESA MISSIONS

The following Tables 2.1 and 2.2 contain pertinent information of some current and all future ESA missions (up to 2004, i.e. Horizon 2000 plus missions are not included) as known to the authors of the study at this time of completing WP 1000 (April 1994). Some missions, in particular in the space science area, belong to a set of candidate missions from which only one or two will be selected as flight missions. Table 2.1 contains the mission descriptions. Table 2.2 contains the space data system elements concerning the space-ground link and the link between ground stations and control and/or data centres.

TABLE 2.1: ESA MISSIONS - MISSION DESCRIPTIONS

Abbreviations: SCIM = Space Science Mission; EOM = Earth Observation Mission; COMM = Telecommunication Mission; STUM = Space Transportation Mission, unmanned; STMM = Space Transportation Mission, manned.

NO	CATEGORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
1	STMM	ARIANE 4/5	Launch Vehicle			
2	EOM	ARISTOTELES	• Primary mission is investigation of the geopotential (gravity and magnetic field): solid earth geophysics, physical oceanography, climatology & global change. • Secondary mission is positioning geodesy: connection of dynamic and inertial reference, monitoring of deformations in seismic areas and of volcanic activities.	• Gravity Gradiometer (GRADIO) (flown in 200 km; reconstitution of earth gravity field at medium and short wave lengths to a spatial resolution of 100 km) • Magnetometers - Scalar magnetometer (to measure the total magnetic field strength) - vector magnetometer with optical attitude sensors (star trackers) (to measure field components) • GPS (Global Positioning System) Tracking System (position measurement to an accuracy of a few centimeters and to provide supplementary data on gravity field).	780x780 km near polar sun synchronous	This mission is unlikely to be approved in the near future
3	COMM	ARTEMIS	Semi-operational Satellite for data relay to and from lower flying satellites	Payload essentially as for DRS (see below)	Geostationary	

NO	CATEGORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
4	STUM	ATV	• Delivery of logistics goods for the space station platform and payloads • Space station reboost functions • Removal of waste consumables and surplus equipment from space station. Demonstration flight in 2001 First operational flight 2002.	• Launch by Ariane 5 • Capability to transfer ca. 14 t of cargo (i.e.payload plus the payload carrying module) from the injection into transfer orbit by Ariane 5 to a space station in low Earth orbit (400-500 km altitude at 51.6° orbital inclination) • Possible cargo configurations include Pressurised and Unpressurised Logistics Carriers (PLC, ULC), fuel and fluid carriers • Supply of power and control data to the cargo during flight and monitoring of the payload • Capability for automated rendezvous and capture or docking • Up to 6-month docked stay in dormant mode • Capability to remove waste consumables and surplus equipment from a space station into a controlled destructive re-entry trajectory • Length typically in the range of 3 - 4 m (without cargo) • Diameter typically in the range of 4 m • Launch mass (including propellant): 5 t plus the mass of the cargo (up to 14 t in the case of 51.6° orbital inclination) • Landing: not applicable (destructive re-entry flight).	Typical space station near earth orbit (400 - 500 km), 51° inclination	
5	SCIM	CLUSTER	Investigating the plasma environment of the Earth by instruments on four spacecraft; positioned so as to provide three dimensional measurements in different regions (northern polar cup region, geotail, magnetopause, bow shock, solar wind). Launch 12/95; mission duration 2.5 years with possibility for extension.	• Electric Field and Plasma Fluctuation Experiment (from DC to 10 kHz, resolution 100 ms) • Spatio-Temporal Analysis of Field Fluctuations Experiment (STAFF) • WHISPER experiment (measurement of total plasma density and continuous survey of one electric component of plasma) • Wideband Plasma Wave (WBD) investigation (measurement of high resolution frequency/time spectra of plasma waves) • Digital Wave Processing Experiment (DWP) • Magnetometers • Electron Drift Instrument (EDI) (measuring drift of emitted electrons at their return) • Cluster Ion Spectrometry (CIS) experiment (measuring 3-dim. ion distribution) • Plasma Electron and Current Experiment (PEACE) (measurement of 3-dim. velocity distribution of electrons) • Imaging Energetic Particle Spectrometer (RAPID) (analysis of suprathermal plasma distributions) • Ion Emitter Experiment (active spacecraft potential control)	Highly excentric earth orbits	
6	SCIM	COBRAS/ SAMBA	Cosmological mission of long duration for the investigation of the early universe in the microwave region. Production of precise sky maps of the anisotropies of the cosmic microwave background. Determination of primordial density fluctuations.	• Radiometer • Sub-Millimeter Telescope with cooled bolometer-Detectors.	Either polar sun-synchronous earth orbit, or L2 or Heliocentric orbit	Candidate for "Medium-3 mission"; Launch 2004 (?)

NO	CATEGORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
7	STMM	COLUMBUS PROGRAMME	Continue and further develop Europe's capabilities in manned spaceflight and ensure the development of Europe's capability to achieve autonomy in the longer term. Launch around 2000.	• Pressurized Laboratory as part of ISSA (launched in 2002) - Launched (probably) with SHUTTLE into 51.6 ° orbit with initial payload of 2 tons. - 8 laterally installed racks, 4 ceiling stowage racks, 4 floor sub-system racks; 4 tons of payload; size somewhat smaller than SPACELAB - Potential European payload complement is BIOLAB, Material Science Laboratory, Fluid Science Laboratory	ISSA orbit	
8	STMM	CTV	• Delivery of crew and payload to space stations in low Earth orbit • Regular return of crew and payload from space stations to Earth • Emergency return capability for space station crews. First unmanned flight in 2001. First manned flight in 2002.	• Launch by Ariane 5 • Orbital propulsion and resource function either integrated into the re-entry vehicle ("monolithic" version) or assured by a man-rated version of the Automated Transfer Vehicle (ATV) • Total launch mass of the whole system up to 18 t, depending on the selected concept, of which typically - 7 - 15 t for the re-entry vehicle - about 5 t for ATV (if the function is not integrated into the re-entry vehicle itself) - 3 - 4 t for launch structures and launch safeguard systems • 4 passengers • 400 kg (2 cbm) of payload upwards and downwards; capability to carry up to 1 t additional payload upwards • Length of the re-entry vehicle typically in the range of 5-7 m • Diameter typically in the range of 4.5 - 5.5 m • Volume inside the re-entry vehicle more than 10 cbm • Aerodynamic lateral manoeuvreing capability ("cross range") 200 - 500 km • Capability to land in Europe (when returning from a space station on a 51.6° inclination orbit) • Landing accuracy: 1.5 - 9 km • Landing system: parachutes and landing shock damping devices (e.g. retro-rockets, airbags) • Land and water landing capability.	ISSA rendezvous and return to earth orbits	
9	COMM	DRS	System of two operational geostationary satellites relaying data between low flying satellites and European ground stations.	• Services - Transfer of data from low earth orbiting spacecraft and launchers to users and ground stations - Communications between low earth orbiting spacecraft and their control stations (audio, video, graphics) - Telecommand links between ground controllers and s/c in orbit and launch vehicles - Ranging operations for position determination of s/c in orbit and possibly launchers. • Telecommunication sub-systems - for DRS - ground link (feeder link): Ka-band (20/30 GHz) system - for inter-orbit link (IOL): S-band, Ka-band and optical link systems. • Coverage (Satellites at 44° West and 59° East) - for feeder link: large parts of Europe plus temporarily dedicated areas outside Europe with steerable antenna - for IOL: low earth orbits up to 850 km all positions except small exclusion zone in mid Pacific.	Geostationary	

NO	CATEGO-RY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
10	EOM	ENVISAT	Polar orbiting platform carrying research-type instruments for earth observation; providing continuity for ERS-missions (element of POEM-1).	• Medium Resolution Imaging Spectrometer (MERIS) • Michelson Interferometric Passive Atmospheric Sounder (MIPAS) • Radar Altimeter-2 (RA-2) • Advanced Synthetic Aperture Radar (ASAR) • Global Ozone Monitoring by Occultation of Stars (GOMOS). • Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) • Advanced Along Track Scanning Radiometer (AATSR) • Scanner for Radiation Budget (SCARAB).	800x800x57°	
11	EOM	ERS 1/2	Polar orbiting (800 km) platform carrying research-type instruments for earth observation.	• Active Microwave Instrument (AMI); C-band radar working as Synthetic Aperture Radar (SAR) or a Wind Scatterometer • Radar Altimeter; a nadir pointing active microwave sensor • Along Track Scanning Radiometer and Microwave Sounder (ATSR/M); passive instrument with four channel infra-red radiometer and two channel microwave sounder; provides images of sea surface and surface temperature, info on water vapor content, observation of clouds, aerosols, haze and ice surface emissivity • Precise Range and Range-rate Equipment (PRARE); providing high precision orbit data • Laser Retroreflector (LR); used for ground based laser tracking • Global Ozone Monitoring Experiment (GOME). (ERS-2)	800x800x57°	
12	STUM	EUREKA MISSIONS	Reusable carrier for microgravity experimentation in very low gravity (10^{-5} g) and for other payload to be deployed and retrieved by the NASA Shuttle. A EURECA 2 mission is still planned for 1996/7 but financing is uncertain.	First flight: • Microgravity Payload - Automatic Mirror Furnace - Solution Growth Facility - Protein Growth Facility - Multi-Furnace Assembly - High Precision Thermostat - Surface Forces Adhesion Instrument • Space Radiation Payload - Exobiology and Radiation Assembly - Radiation Dosimeter • Space Science Research Payload - Solar Spectrum Instrument - Solar Constant and Variability Instrument - Occultation Radiometer - Wide Angle Telescope - Timeband Capture Cell Experiment • Space Technology Demonstration Payload - Radio Frequency Ion Thruster Assembly - Inter-Orbit Communication Instrument - Advanced Solar Gallium Arsenide Array.	400x400x28°	A second flight under a commercial programme is currently under consideration

NO	CATEGO-RY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
13	SCIM	FIRST	Far infrared and sub-millimeter SPACE telescope. Launch 2006; mission duration 2 years (?)	• Multi-Frequency Heterodyne Receiver • Far Infrared Instrument	1000x70000x7°, northern apogee	
14	SCIM	HUBBLE	High angular resolution optical astronomy with an accuracy of 0.1 in visible, ultraviolet and infrared light (2.4 m diameter primary mirror).	• 2.4 m diameter reflecting telescope with an effective focal length of 57 m achieved through a Ritchey-Chrétien Cassegrain configuration. • The detector instruments are: - Wide Field/Planetary Camera - Faint Object Camera (provided by ESA) - Faint Object Spectrograph - Goddard High-Resolution Spectrograph - High-Speed Photometer.	590x590x28°	Ongoing mission
15	SCIM	HUYGENS	Investigation of the planet Saturn and of its moon Titan; spacecraft consists of the NASA Saturn Orbiter (CASSINI) and the ESA HUYGENS probe, which will be dropped into the Titan atmosphere. Launch 10/97, encounter 2004.	Payload of Probe (39.9 kg): • Atmospheric Structure Instrument (ASI) (Atmosphere temperature and pressure profile, winds and turbulence) • Probe Infra-Red Laser Spectrometer (PIRLS) (Vertical profile of trace species; Nephelometry) • Gas Chromatograph/Neutral Mass-Spectrometer (GC/MS) (Atmosphere composition profile; Aerosol analysis) • Aerosol Collector and Pyrolyser (ACP) (Aerosol composition profile GC/MS is used as detector) • Descent Imager/Spectral Radiometer (DI/SR) (Atmospheric composition and cloud structure; Surface imaging) • Lightning and Radio-Emission Detector (LRD) (Titan lightning characteristics) • Surface-Science Package (SSP) (Titan surface state and composition) • Doppler Wind Experiment (DWE) (Probe Doppler tracking from the orbiter for zonal wind-profile measurement) • Radar Altimeter Science (RAS) (Surface roughness and reflectivity; Subsurface sounding).	Interplanetary	
16	SCIM	INTEGRAL	Gamma-Ray Astronomy 15 keV - 10 MeV using High Resolution Spectroscopy and Fine Imaging. Concurrent monitoring in X-Ray and optical bands. Launch 04/2001; mission duration 2 - 10 years.	• Germanium Spectrometer • Caesium Iodide Imager • Monitors: - X-Ray Monitor - Optical Transient Camera	48000x115000x51.6° (Proton) or 4000x68000x65° (Ariane 5) or 4000x117000x28.5° (Titan III)	

NO	CATEGO-RY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
17	SCIM	INTERMARS-NET	A contribution to the international network of Mars stations. 3 or 4 landers communicating via a Mars orbiting relay satellite. Candidate for "Medium-4 mission"; Launch 2005 (?)	• Seismometer • Panoramic Camera System • Descent Imager • Close-up Imager • α-proton X-ray Spectrometer • Neutron Detector • Differential Thermal/Evolved Gas Analyser • Mössbauer Spectrometer • Meteorological Package • Atmospheric Structure Experiment • Solar-UV Dosimeter • Permanent Magnet Array • Triaxial Magnetometer.	Transfer to Mars and landing trajectories	• In Phase A • Candidate for Medium 3 Mission (Launch 2003/04) • [3]
18	SCIM	ISO	Will be used (in an observatory mode) to observe all classes of astronomical objects in the infrared ranging from planets and comets in the solar system to the most distant galaxies. Launch 09/95; mission duration 1.5 - 1.8 years.	• Camera with polarimetric capabilities (ISOCAM) • Imaging Photopolarimeter (ISOPHOT) • Short-wavelength Spectrometer (SWS) • Long-wavelength Spectrometer (LWS).	Highly eccentric (70000x1000 km) orbit	
19	EOM	METEOSAT	Imaging of the earth from geostationary position using different wavelengths plus dissemination of rectified images and data collection.	• Three Channel (visible, IR, Water Vapor) high resolution (2.5 km for VIS, 5 km for IR and WV) Radiometer • Two Dissemination Channels • Data Collection Facility for 66 Channels • Advanced Meteorological Data Distribution System (e.g for Weather Fax Transmission)	Geostationary	
20	EOM	METEOSAT SECOND GENERATION	Increasing performance of current generation METEOSAT primarily by modernising and enhancing instruments; continued use of geostationary position.	• Higher number of instruments covering more frequency bands • Increased resolution of instrument measurements • Enhancement of communication package (relay/disseminate meteorological data, collect data from earth bound data collection platforms).	Geostationary	

NO	CATEGO-RY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
21	EOM	METOP	Polar orbiting operational Meteorological Satellite for routine meteorology and climate monitoring as part of the EUMETS-AT Polar System (EPS). Will be operated in close cooperation with NOAA satellites (EPS will eventually provide three morning satellites, NOAA with NOAA-O,-P,-Q the three afternoon satellites	• Advanced Very High Resolution Radiometer (AVHRR/3): global imagery, global sounding, ocean measurements, clouds and earth radiation budget, land measurement; provided by NOAA • High Resolution Infrared Sounder (HIRS/3): global sounding, atmospheric minor constituents (Ozone); NOAA • Advanced Microwave Sounding Unit (AMSU-A1, AMSU-A2): global sounding, sea ice; NOAA • Microwave Humidity Sounder (MHS): global sounding, cloud and earth radiation budget, sea ice; EUMETSAT • Advanced ARGOS DCS-2: data collection and location, collection of climate data; NOAA/CNES • Infrared Advanced Sounder Interferometer (IASI): global sounding, ocean measurements, clouds and earth radiation budget, atmosph.minor constituents, land measurements; CNES/ASI • Advanced Scatterometer (ASCAT): ocean measurements; ESA • Multifrequency Imaging Microwave Radiometer (MIMR): ocean and land measurements, sea ice, water vapour content, cloud & earth radiation budget, precipitation; ESA • Ozone Monitoring Instrument: atmospheric minor constituents; NIVR/ASI • Scanner for Radiation Budget (ScaRaB): cloud and earth radiation budget; CNES • Search and Rescue (SAR): humanitarian mission; NOAA • Space Environment Monitor (SEM): monitoring of the local space plasma and radiation environment; NOAA	Sun-synchronous, near polar, morning satellite	Ref. [17]
22	SCIM	MORO	Geochemical characterisation of the moon surface by means of topography, gravimetry, the physics of cosmic rays and the observation of transport processes in the magneto-ionosphere of the earth. Candidate for "Medium-4 mission"; Launch 2005 (?)	• Ultraviolet Visible and Infrared Mapping Spectrometer • Lunar Microwave Instrument (Interferometric SAR) • Anti-Matter Assessment Research Instruments • Spectrometer for detection of energetic neutral atoms.	Moon transfer and lunar orbit	• Currently in Phase A • Candidate for Medium 3 Mission (Launch 2003/04)
23	SCIM	ROSETTA	Comet Rendezvous Mission (Comet orbiter and possibly lander) Launch 2003; mission duration	• REMOTE SENSING INVESTIGATIONS - Remote Imaging System - Visible and Infrared Spectral and Thermal Mapper • IN-SITU INVESTIGATIONS - Gas and Ion Mass Spectrometer - Cometary Matter Analyser - Scanning Electron Microprobe and Particle Analyser - Dust Production Rate and Velocity Analyser - Plasma Package • OBSERVATORY INVESTIGATIONS - Gamma Ray Spectrometer - Alpha/proton/X-Ray Fluorescense Spectrometer - Neutron Spectrometer - In-Situ Imaging System - Accelerometers - Permitivity Probe - Evolved Gas Analyser	Interplanetary	

NO	CATEGO-RY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
24	SCIM	SOHO	Study of the sun; the acceleration and propagation of the solar wind, its interaction with the earth; plasma processes in both the solar and magnetospheric context.	• Solar Ultraviolet Emitted Radiation (SUMER) (plasma flow characteristics) • Coronal Diagnostic Spectrometer (CDS) (transition region and corona temperature and density) • Extreme-Ultraviolet Imaging Telescope (EIT) (evolution of chromospheric and coronal structures) • Ultra-Violet Coronograph Spectrometer (UVCS) (electron and ion temperatures, densities and velocities in corona) • Large-Angle and Spectrometric Coronograph (LASCO) (structures evolution, mass, momentum and energy transport in corona) • Solar Wind Anisotropies (SWAN) (solar-wind mass flux anisotropies and temporal variations) • Charge, Element and Isotope Analysis (CELIAS) (ionic energy distribution and composition) • COSTEP/ERNE Particle Analyser Collaboration (CEPAC) (energy distribution and particles, energy spectrum and composition) • Global Oscillations at Low Frequencies (GOLF) (global velocity and magnetic field oscillations) • Variability of Solar Irradiance and Gravity Oscillations (VIRGO) (irradiance oscillations and solar constant) • Michelson Doppler Imager (MDI) (velocity oscillations)	Orbit around the sun-earth Lagrangian Point L1	
25	STMM	SPACELAB MISSIONS	Manned experimentation in space; laboratory module transported in cargo bay of Shuttle (13 missions so far). Currently no European missions planned.	• Microgravity research facilities - Biorack (cell & developmental biology) - ESA Anthrorack (human physiology/heart facility, pulmonary research, haemodynamics, metabolism) - Autonomous Fluid Physics Module (capillarity, wetting coalescense, transient) - Critical Point Facility (critical point research at low temperature, 20-70°) - Bubble Drop and Particle Unit (flow phenomena, drop/bubble dynamics) - Advanced Gradient Heating Facility (semiconductor crystal growth & metal solid. research) - Advanced Protein Crystallization Facility (growth of single crystals of proteins & other organic materials) - Liquid Structure Facility (study of pattern formation) • Earth observation facilities - Metric Camera - Microwave Remote Sensing Instrument • Astronomy - Very Wide Field Camera (high quality sky images) - Instrument Pointing System (hyper-precise instrument pointing/stability) - X-ray Spectrometer (galactic source energy spectra) • Space Science Facilities - Grille Spectrometer (Solar Constant) - Plasma Physics Instruments (earth environment, plasma effects)	Typical Shuttle orbit: 400x400x28°	
26	SCIM	STARS	Investigation of stellar structures and evolution. Candidate for "Medium-3 mission"; Launch 2003	• Imaging White Light Photometer • Imaging UV Fourier Transform Spectrometer • UV Line Monitor	high orbit; possibly at L1	• Currently in Phase A • Candidate for Medium 3 Mission (Launch 2003/04)

NO	CATEGO-RY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
27	SCIM	STEP	Investigations in fundamental physics (test of equivalence principle) and in geodesy. Candidate for "Medium-3 mission"; Launch 2003	• Equivalence Principle Experiment • Spin Coupling Experiment • Constant of Gravity G and Inverse Square Law Experiment • Geodesy • Aeronomy	350-400x350-400x97°	• Currently in Phase A • Candidate for Medium 3 Mission (Launch 2003/04)
28	SCIM	ULYSSES	Investigation of solar phenomena outside the ecliptic: solar wind, structure of sun/wind interface, heliospheric magnetic field, solar radio bursts and plasma waves, solar X-rays, solar and interplanetary energetic particles, galactic cosmic rays, interstellar/interplanetary neutral gas and dust.	• Cosmic-ray and Solar Particle Investigation (COSPIN) • Dust Experiment (DUST) • Energetic Particle Composition Experiment (EPAC) • Magnetic Field experiment (Flux Gate Magnetometer/Vector Helium Magnetometer) (FGM/VHM) • Interstellar Neutral Gas Experiment (GAS) • Solar X-Ray/Cosmic Gamma-Ray Burst experiment (GRB) • Radio-Science Gravitational Wave Experiment (GWE) • Heliosphere Instrument for Spectra Composition and Anisotropy at Low Energies (HI-SCALE) • Radio-Science Solar Corona Experiment (SCE) • Solar-Wind Ion Composition Spectrometer (SWICS) • Solar-Wind Observations over the Poles of the Sun: Ion and Electron Measurements (SWOOPS) • Unified Radio and Plasma Wave Experiment (URAP).	Orbiting outside the ecliptic around sun achieved through Jupiter fly-by	Ongoing mission; Reference: ESA Bulletin 63 and 72;
29	SCIM	XMM	Achieving advances in the X-ray physics (at the end of the 1990s). Launch 1999; mission duration 2 years, extended 10 years	• X-Ray Physics tasks: - broadband spectroscopy between 0.1 and 10 keV with resolving power E/ΔE of between 5 and 60 - Medium-resolution spectroscopy between 01. and 3 keV with resolving power of over 250 at 0.5 keV - Simultaneous optical monitoring between 2000 and 6000 Å to a limiting magnitude of 24.5 • This is achieved through the instruments: - 3 mirror modules - 3 CCD array cameras, one at the prime focus of each telescope - 2 reflection grating spectrometers fitted to two of the telescopes - 1 optical monitor. • Long-duration observatory available to the worldwide astronomical community	High eccentric 48 hour orbit (7000/117000 km), apogee in northern hemisphere, inclination 70°	

TABLE 2.2: ESA MISSIONS - SPACE DATA SYSTEM ELEMENTS AND OPERATIONS SCENARIOS

This table contains the space data system elements in terms of ground stations, control and data centres including the data links between these facilities. Those mission scenarios which represent interoperation scenarios, i.e. which are the subject of the remaining chapters in this report and of the study work in WPs 2000 and 3000 are underlined. For interpretation of the link designations see Figure 2.1.

NO	NAME	SPACE-GROUND LINK TERMINALS/SYSTEMS		CONTROL CENTRES		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
1	ARIANE 4/5	- Ariane tracking network - Bermuda station (for upper stage tracking)		Ariane control centre			(a) EPI-EG-EC for launcher control (b) <u>EPI-NG-EC</u> for upper stage tracking	
2	ARISTOTELES	Kiruna	Kiruna plus possibly other European stations	ESOC	ESOC		(a) EPI&PI-EG-EC for platform and payload control	
3	ARTEMIS	Fucino	User stations	Fucino	Fucino		(a) EPI&PI-EG-EC for platform and payload management	
4	ATV	DRS	DRS	ESOC (?); strong interface with control centre of vehicle which is destination or point of departure	ESOC (?) strong interface with control centre of vehicle which is destination or point of departure		(a) EPI-ES-EC for platform control during ascent and descent (b) <u>EPI-ES-EC-NC</u> during proximity operations e.g. with Space Station (c) <u>EPI-NPI</u> during proximity operations	
5	CLUSTER	Odenwald, Redu plus DSN (Goldstone & Canberra)	- for low data rate payload: Odenwald & Redu - for high data rate US payload Goldstone & Canberra	ESOC	- Joint Science Operation Centre in Chilton (UK): coordinates payload operations and transmits commands to ESOC - ESOC performs payload ops	Done by PIs	(a) EPI-EG-EC and (b) <u>EPI-NG-EC</u> for LEOP/TOP (c) EPI&PI-EG-EC and (d) <u>EPI&PI-NG-EC</u> for commissioning (e) EPI&PI-EG-EC for routine phase (f) <u>NPI-EPI-NG-ND</u> for high rate data of specific US payload ED in UK	
6	COBRAS/SAMBA	Either European stations or DSN plus Weilheim	as for TTC	ESOC	ESOC		(a) EPI&PI-EG-EC or (b) <u>EPI&PI-NG-EC</u> for platform and payload control	

NO	NAME	SPACE-GROUND LINK TERMINALS/SYSTEMS		CONTROL CENTRES		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
7	COLUMBUS PR-OGRAMME	TDRSS & DRS (ground station for DRS is COLUMBUS Earth Terminal (CET) at ESOC)	TDRSS & DRS	COFCC at GSOC plus SSCC at JSC (for certain mission phases)	COFCC at GSOC (for European payload) plus POIC at MSFC (for US payload)	COFCC, MUSC (in Köln) and other European support centres for the European payload; PDSS at MSFC for US payload	(a) EPI&PI-ES-ECPI&PI for control of COF including its European payload from COFCC using DRS and CET (b) NPI-EPI-ES-ND for data of US payload in COF (c) EPI&PI-NPI-NS-NCPI-ECPF&PI for use of TDRSS during certain mission phases for COF control by COFCC (d) EPI&PI-NPI-NS-NCPI for COF platform and payload control by SSCC at JSC during certain mission phases	The operation scenarios are those for ESA sponsored payload and for US payload in the COF
8	CTV	DRS	DRS	ESOC (?); strong interface with control centre of vehicle which is destination or point of departure	ESOC (?) strong interface with control centre of vehicle which is destination or point of departure		(a) EPI-ES-EC for platform control during ascent and descent (b) EPI-ES-EC-NC during proximity operations, e.g. with Space Station (c) EPI-NPI during proximity operations	
9	DRS	Fucino	User stations	Fucino	Fucino		(a) EPI&PI-EG-EC for platform and payload management	
10	ENVISAT	- LEOP: Wallops, Poker Flat, Kiruna and probably other stations as for ERS1/2 - Rout.Phase: Kiruna	Kiruna, Maspalomas, Fucino plus Fairbanks and other user stations	ESOC	ESOC	ESRIN and others	(a) EPI-NG-EC and (b) EPI-EG-EC for LEOP platform control (c) EPI&PI-EG/S-EC for platform and payload control (d) EPI-EG/S-ED for payload data handling (e) EPI-NG-ND for payload acquisition and data handling by NOAA	
11	ERS 1/2	- LEOP: Wallops, Poker Flat, Perth, Santiago, Kiruna (and others) - Rout.Phase: Kiruna	Kiruna, Maspalomas, Fucino plus Fairbanks and other user stations	ESOC	ESOC	ESRIN and others	(a) EPI-NG-EC and (b) EPI-EG-EC for LEOP platform control (c) EPI&PI-EG-EC for platform and payload control (d) EPI-EG-ED for payload data handling (e) EPI-NG-ND for payload acquisition and data handling by NOAA	
12	EURECA MIS-SIONS	- TDRSS for deployment and retrieval - Maspalomas, Kourou and Perth for routine phase	Maspalomas, Kourou and Perth	ESOC	ESOC		(a) EPI-Shuttle-NS-NC-EC for deployment and retrieval (b) EPI&PI-EG-EC for routine phase	
13	FIRST	Villafranca, Perth	as for TTC	ESOC	ESOC		(a) EPI&PI-EG-EC for platform and payload control	
14	HUBBLE	TDRSS	TDRSS	GSFC	GSFC	Various	(a) NPI&PI-NS-NC for platform and payload control (b) NPI-NS-ND for payload exploitation in the US (c) NPI&EPI-NS-ED for payload exploitation in Europe	

NO	NAME	SPACE-GROUND LINK TERMINALS/SYSTEMS		CONTROL CENTRES		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
15	HUYGENS	DSN	DSN	JPL	- ESOC acts as POCC - JPL performs payload ops		(a) EPI-NPI-NG-NC for LEOP and cruise phase (b) EPI-NPI-NG-NC-EC for descent and continuing phase EPI designates the Huygens s/c	
16	INTEGRAL	Villafranca	Villafranca & DSN (Goldstone & Canberra)	ESOC	ESOC plus Science Operation Centre at ESTEC	Science Data Centre in Europe	(a) EPI&PI-EG-EC and (b) EPI&PI-NG-EC for platform and payload control (c) EPI&PI-NG-ED for payload data (possibly also via EC)	
17	INTERMARSNET	DSN	DSN	ESOC	ESOC		(a) EPI&PI-NG-EC or (b) EPI&PI-NG-NC for platform and payload control	
18	ISO	Villafranca	Villafranca & DSN (Goldstone)	Villafranca	Villafranca		(a) EPI&PI-EG-EC and (b) EPI&PI-NG-EC for platform and payload control	
19	METEOSAT SECOND GENERATION	Fucino	Fucino	EUMETSAT CC	EUMETSAT CC		(a) EPI&PI-EG-EC for platform and payload control (b) EPI-EG-ED for payload data handling (c) EPI&PI-NG-NC for s/c operated by NOAA	EUMETSAT has been considered equivalent with ESA for the purpose of this study
20	METEOSAT	Odenwald	Odenwald plus user stations	ESOC	ESOC		(a) EPI&PI-EG-EC for platform and payload control (b) EPI-EG-ED for payload data handling (c) EPI&PI-NG-NC for s/c operated by NOAA	
21	METOP	- LEOP: Wallops, Poker Flat, European polar station and probably other stations as for ERS1/2 - Rout.Phase: European polar station	Several globally distributed user stations (also in the US)	EUMETSAT CC	EUMETSAT CC		(a) EPI-NG-EC and (b) EPI-EG-EC for LEOP platform control (c) EPI&PI-EG/S-EC for platform and payload control (d) EPI-EG/S-ED for payload data handling (e) EPI-NG-ND for payload acquisition and data handling by NOAA (f) NPI-EPI for NOAA payload on ESA/EUMETSAT platform	EUMETSAT has been considered equivalent with ESA for the purpose of this study (the satellite will be developed by ESA anyway). The data handling system will be CCSDS compatible
22	MORO	Weilheim plus possibly DSN (?)	as for TTC	ESOC (?)	ESOC (?)		(a) EPI&PI-NG-EC or (b) EPI&PI-NG-NC for platform and payload control	
23	ROSETTA	Weilheim or Odenwald (?), Perth plus possibly DSN	as for TTC	ESOC	ESOC		(a) EPI&PI-EG-EC and (b) EPI&PI-NG-EC (if DSN is used) for platform and payload control	
24	SOHO	DSN 26 m	DSN 26 m	Transportable POCC (TPOCC) at GSFC	SOHO Experiment Operations Facility (EOF) at GSFC	Data processing facilities at GSFC; processes and distributes data to EOF to investigators and to ESA	(a) EPI&PI-NG-NC for platform and payload control (b) NPI-EPI-NG-NC-ND for NASA payload data handling (c) EPI-EPI-NG-NC-ED for ESA payload data handling	

NO	NAME	SPACE-GROUND LINK TERMINALS/SYSTEMS		CONTROL CENTRES		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
25	SPACELAB MISSIONS	TDRSS	TDRSS	JSC	MSFC plus GSOC		(a) EPI-Shuttle-NS-NCPI for platform control (b) EPI-Shuttle-NS-NCPI-ECPI for control of ESA payload	ECPI is GSOC
26	STARS	Villafranca	as for TTC	ESOC	ESOC		(a) EPI&PI-EG-EC for platform and payload control	
27	STEP	See remark	See remark	ESOC	ESOC		(a) EPI&PI-NG-NC and (b) NPI-EPI-NG-NC for option 1 (ESA-NASA cooperative mission), for platform and payload control (c) EPI&PI-EG-EC for option 2 (ESA mission), for platform and payload control	There seem to be two options for this mission: an NASA-ESA cooperation in which NASA would do mission operations (GSFC plus DSN (?)), or an European mission where ESOC would perform control and the European station network would be used.
28	ULYSSES	DSN	DSN	JPL	JPL	During real-time events in the Science Support Area of JPL; otherwise in various institutes of PIs	(a) EPI&PI-NG-NC for platform and payload control (b) NPI-NG-ND for rt events and for US PIs (c) EPI-NG-NC-ED for European PIs	The routing of experiment data in routine phases is not quite clear from the available information. However, this mission is quoted for historical reasons anyway. Therefore, it will not appear in Table 3.1
29	XMM	Perth	Perth	ESOC	- Science Ops Contr. Ctre. in Vilfra - ESOC performs payload ops		(a) EPI&PI-EG-EC for platform and payload control (b) EPI-EG-ED for payload data handling and scheduling support	

2.3 NASA MISSIONS

The following Tables 2.3 and 2.4 contain pertinent information on some current and the future NASA missions as published in the documents [1] and [3]. Document [1] is being updated regularly, the latest issue available was that of August 1995. The missions and mission characteristics have of course somewhat changed since June 1994.(1) It was found, that these changes did not lead to any changes in the study conclusions. Thus, the June 94 issue was kept as the baseline information source on the GSFC sponsored NASA missions. Document [3] contains information on the JPL sponsored missions. Newer issues of this document did not become available during the course of the study. Table 2.3 contains the mission descriptions. Table 2.4 contains the space data system elements concerning the space-ground link and the link between ground stations and control and/or data centres.

TABLE 2.3: NASA MISSIONS - MISSION DESCRIPTIONS

Abbreviations: SCIM = Space Science Mission; EOM = Earth Observation Mission; COMM = Telecommunication Mission; STUM = Space Transportation Mission, unmanned; STMM = Space Transportation Mission, manned; GEN = Other missions.

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
35	SCIM	ACE	Advanced Composition Explorer; measures particles of Solar, interplanetary, interstellar, and galactic origins spanning the energy range from 1 keV/nucleon (Solar Wind) to several hundred MeV/nucleon (galactic cosmic rays). Additionally, ACE will study abundances of essentially all isotopes from H to Zn using high resolution spectrometers. Launch 08/97, duration up to 5 years.	No detailed information available to the author.	Sun-Earth Libration Point L1	Reference [3]
36	GEN	ARIANE Launch Vehi-cle Support	Telemetry and tracking support for Ariane 3rd stage operations	Not applicable.	Launcher trajectory	Reference [1]
37	SCIM	AXAF	Improved X-ray astronomy research (10 times the resolution and 100 times the sensitivity than earlier missions (e.g. HEAO)). Launch: 10/98	X-ray spectrometer	Polar earth orbit, sun-synchron ous	Reference [1]

1 For example newly mentioned missions are: EOS-LALT & -CHEM, Relativity, SMEX-4 (Transition Region and Coronal Explorer, TRACE), SMEX-5 (Wide-Field Infrared Explorer), Medium Class Explorer Missions, Advanced Earth Orbiting Satellite (ADEOS-1). Missions not yet mentioned are: FAST (=SMEX-3) and TIMED-H & -L.

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
38	SCIM	CONTOUR	Comet Nucleus Tour; is a Discovery type mission for flyby of several comets. Launch 08/2003; mission duration 5 years	• Imaging instruments • Dust analyser • Impact counter • Neutral and Ion spectrometer	Heliocentric with distances of 0.28 through 1.26 AU	Reference [3]
39	EOM	EOS	The Earth Observing System (EOS) is a multi-mission programme (altogether 17 satellites) with the objective of acquiring the geophysical, chemical, and biological information necessary for intense study of the earth. The EAO data and information system will build up over 10 years and then function for at least 15 years to allow accurate modelling of the processes that control the environment. During the 15 year observation period of the EOS mission, as many as five spacecraft (one from each series) will be performing normal operations at the same time. In addition there may be two spacecraft from the same series in orbit during a s/c replacement period of up to six months. Launches starting 06/98	The programme involves the operation of numerous instruments on multiple s/c placed in polar and mid-inclination orbits in support of multiple disciplines within the Earth science user community. The 5 different series of s/c are: (1) EOS-AM (ante meridiem = morning orbit), (2) EOS-PM (post meridiem = afternoon orbit), (3) EOS-AERO (Aerosoles), (4) EOS-ALT (Altimetry, (5) EOS-CHEM (Chemistry)	Polar and mid-inclination earth orbits	Reference [1] See also Aviation Week Feb 21, 1994 page 36
40	STUM	EURECA-2	Launch and Retrieval Missions. EURECA is released from the Shuttle in space by the RMS, is then activated and boosted to its operational orbit (500 x 500 km) by its own propulsion system. Throughout the routine mission, operational control and ground support are provided by ESOC EURECA returns to a retrievable orbit at the end of the mission, where it is picked up by the Shuttle using RMS.	See Table 2.1	500 x 500 km, 28 degrees inclination	Reference [1]
41	SCIM	FAST (SMEX-3)	FAST is the second explorer of the SMEX multi-mission programme. Its primary objective is to investigate the plasma physics of the low altitude auroral zone. The principle science measurements will be taken when the s/c passes through the earth's auroral zones, which is the circular region at magnetic latitudes between 65 and 75 degree. Launch: 08/94	FAST instruments include electric and magnetic field instruments and plasma particles instruments such as the • Electrostatic Analyser (ESA instrument) • Time-of-flight Energy Analysing Mass Spectrometer (TEAMS) • Wave/Particle Correlator (WPC)	350 x 4200 km 83 degrees orbit, not sun-synchronous	Reference [1]

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
42	SCIM	FUSE	FUSE is Far Ultraviolet (FUV) Spectroscopy Mission with sufficient sensitivity to study FUV sources throughout the solar system, the galaxy and even at extra-galactic distances. A secondary objective is to study spectra over the Extreme Ultraviolet (EUV) region with moderate resolution. Launch 06/2000, duration up to 5 years	No detailed information available to the author.	High eccentric orbit: 600 x 71000 km with 28.7 degrees inclination	Reference [3]
43	EOM	GOES	Geostationary Operational Environmental Satellite (Series I through M): these newer generation environmental satellites in geostationary orbit are 3-axis stabilized. Launches between 04/94 and 12/03	• Imager and Sounder Subsystem: provides earth imaging in both the visible and IR spectra • Space Environmental Monitoring Subsystem: measures magnetic field X-ray emissions, proton and alpha particle flux, and high energy electrons • Search and Rescue Subsystem: detects and relays distress signals from aircraft and some classes of marine vehicles to a SAR ground station • Data Collection System: receives and transmits uplink data from remote data collection platforms to the Wallops Island, VA/Command and Data Acquisition (WLP/CDA) station; this system also receives and relays interrogation signals from the WLP/CDA station to the platforms • WEFAX System: relays weather facsimile (WEFAX) from the WLP/CDA ground station to the user community.	Geostationary 75 and 135 degrees west	Reference [1]
44	SCIM	GRAND TOUR CLUSTER	This Space Physics mission consists of 4 spinning spacecraft with instruments similar to those on ISTP Cluster (see line 5 of Table 2.1). The scientific objectives of the mission seems to be the same. Unlike ISTP Cluster, this mission will have communications between spacecraft, using VHF, to obtain relative position information. Launch 99; mission duration 5 years.	No detailed information available to the author.	Several orbits: 2x30 RE equatorial, 8x235 RE in lunar plane (through double lunar swing-by), and 10x30 RE polar	Reference [3]
45	SCIM	HESP	High Energy Solar Physics: carries a single High Energy Imaging Spectrometer (HEIS) instrument to detect solar flares. Launch 01/99; mission duration 3 years.	High Energy Imaging Spectrometer	600x600 km sun-synchronous polar earth orbit	Reference [3]
46	SCIM	IRAM a.k.a. SIRTF	Infrared Astronomy Mission. Launch 2000; mission duration 5 years (!)	• Multi-band imaging photometer • Infrared array camera • Infrared spectrometer	Heliocentric orbit trailing the earth at a rate of 0.11 AU/year	Reference [3]

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
47	EOM	LANDSAT-7	The Landsat-7 s/c will provide the capability to remotely sense and collect data for the production of multi-spectral imagery of the earth's surface. The project will continue to make Landsat type data available for US civil, national security, and private sector as well as academic, foreign, and commercial uses and to seek to expand the use of such data for global change research and national security purposes. Launch: 01/98.	• Enhanced Thematic Mapper Plus (ETM+)	705 km, sun-synchronous polar orbit, 10:00 am descending	Reference [1]
48	SCIM	MARS BAL-LOON	Balloons dropped on Mars as instrument carriers Launch 01/99; Mars orbit insertion 12/99	No detailed information available to the author.		Reference [4]
49	SCIM	MARS OB-SERVER D1 and D2 PAY-LOAD	Payload to be landed on Mars; Mars orbiter acts as data relay	No detailed information available to the author.		Reference [4]
50	SCIM	MESURE	Mars Environmental Survey Pathfinder and Lander including micro-rovers; comprises small landing vehicles distributed over the Martian surface to form eventually a global network. Launch of Pathfinder end 96 with Mars orbit insertion 10/97; launch of first Lander in 01/2001 and of second Lander in 04/2003.	No detailed information available to the author.		Reference [4]; the complete Mars programme is still under discus-sion and far from being approved.
51	SCIM	NEAR	Near Earth Asteroid Rendezvous mission; adopted as second "Discovery class" mission (simple s/c, having focussed scientific objectives, whose development costs does not exceed 150 M$). Flyby of 2019 Van Albada in July 98, of 4660 Nereus in January 2000 etc. Launch 01/98; mission duration 3 years, extended mission phase 8 years	• Visible imager • Gamma ray spectrometer • Imaging spectrograph • Laser altimeter • Magnetometer	Heliocentric and around an asteroid; distance up to 2.25 AU.	Reference [3]

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
52	EOM	NOAA	The NOAA series K, L, and M, missions provide advanced operational satellites and sensors for use in the National Environmental Satellite, Data and Information Service (NESDIS). These spacecraft are designed to provide an economical and stable platform for the advanced instruments for measurements of the earth's atmosphere and surface, cloud cover, and the proton and electron flux near the earth. The s/c will also have the ability to receive, process, and retransmit data from free-floating balloons and buoys, and remote automatic observation stations. Launches: 05/95, 08/96 and 11/97	No detailed information available to the author.	833 km and 870 km, sun-synchronous polar earth orbits, 7:30 descending and 13:40 ascending	Reference [1]
53	EOM	NOAA	The NOAA series O, P, and Q missions are advanced meteorological satellites which will be used in combination with EUMETSAT satellites. Launches: from 2001 onwards	No detailed information available to the author. Beside the NOAA payloads there will be EUMETSAT payloads on the NOAA platforms. The satellites will be operated in cooperation/coordination with the METOP programme (see Table 2.1)	800x800 km polar earth orbit	Reference [3]
54	SCIM	PLUTO FLY-BY	A pair of very low mass s/c (payload ≈ 100 kg dry mass) are being launched in 99. A 6.5 to 8 year cruise phase is planned. The first flyby will take a 200 picture mosaic of Pluto and its moon Charon. The second spacecraft will encounter Pluto and Charon six months later and will image the other side of both Pluto and its moon., observe any climate changes, and possibly image new targets identified during the first flyby. Launch 01/99; mission duration 8 years.	No detailed information available to the author.	Interplanetary	Reference [3]
55	EOM	SeaStar/Sea-Wifs	The objective of SeaWifs is desired to estimate ocean colour, and to derive from these measurements, various biological indicators and other useful scientific products. These measurements are important to understand the role of the oceans in the global carbon cycle and impacts on global climate. Lifetime 10 years. Launched by Pegasus. Launch: 08/94	No detailed information available to the author.	705x705 km, sun-synchronous earth orbit	Reference [1]
56	SCIM	SOLAR PIO-NEER	Investigate the near solar region below 60 R. Launch 2005; mission duration 6 years.	No detailed information available to the author.	Out of ecliptic after Jupiter flyby; over north pole of the sun; passing the sun equator at 4 R_s	Reference [3]

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
57	STMM	Space Station (Alpha)	Space Station is an international facility to provide a permanent outpost to live and work productively in space. There are three phases: • Phase 1: Expands the previously planned joint participation by US and Russian crews in MIR and SHUTTLE operations • Phase 2 (starts 05/97): Combines the previously planned and the Russian hardware to create an advanced orbital research facility with human-tended capability • Phase 3: (starts 01/98) Completes the construction of the facility to support a permanent human presence.	• US components: nodes, laboratory module, structure and truss segments with photovoltaic (PV) arrays, mini pressurised logistics module, habitation module, pressurised mating adapter, cupola, unpressurised logistics carrier. • Russian components: service module, docking module, research module, trusses with gyrodynes and PV array, resupply and support vehicles. • Joint US/Russian components: airlock, energy block, Soyus Assured Crew Return Vehicle (ACRV), batteries, solar dynamic system, PV arrays. • International partners components: JEM, JEM exposed facility, COF, Mobile Servicing System (MSS).	352 x 407 km, 51.6 degrees inclination	Reference [1]
58	STMM	SPACELAB	See Table 2.1	See Table 2.1; there is no further consideration of specific SPACELAB missions, i.e. interoperability aspects are discussed with respect to the general SPACELAB operations scenario. The US missions quoted in [1] are: • Astronomy-2 (12/94) • ATLAS-3, Atmospheric Laboratory for Applications and Science - 3 (10/94) • IML-2, International Microgravity Laboratory - 2 (07/94) • Life Science-3 (02/96) • SRL-1, Space Radar Laboratory (04/94) • USML-2, United States Microgravity Laboratory-1 (09/95)	See Table 2.1	
59	SCIM	SWAS (SMEX)	Submillimeter Wave Astronomy Satellite: SWAS is the third explorer of the Small Explorer (SMEX) multimission programme. The SWAS mission is an outgrowth of the scientific interest in the exploration of the submillimeter wavelength region astronomy. The SWAS mission is designed to study molecular clouds in the galactic plane, providing a mini and full survey of the clouds leading towards the development of maps. It will also perform quick-look chemistry on the structure and content of these molecular clouds, and will research extragalactic sources. Launch: 06/95	Cassegrain telescope with acousto-optical spectrometer	600 x 600 km, 65 degrees inclination	Reference [1]

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
60	SCIM/EOM	TIMED (-H and -L)	Termosphere, Ionosphere, Mesosphere Energetics and Dynamics; one high inclination (-H) and one low inclination (-L) satellite. Focus is on atmospheric dynamics between approximately 60 km and 180 km. Whereas in-situ measurements obtain state parameters down to about 150 km, remote measurement techniques will examine the atmosphere at lower altitudes where in-situ measurements are not feasible. The need for simultaneous and overlapping coverage of the entire altitude range requires that both in-situ and remote measurements be performed by more than one s/c and that both types of measurements be feasible from either elliptical or circular orbits. The H-s/c moves on a high inclination and the L-s/c on a low inclination orbit. Launches: TIMED-H 11/98, TIMED-L 01/99	No detailed information available to the author.	• TIMED-H: 400 x 400, 95 degrees • TIMED-L: 400 x 400, 49 degrees	Reference [1]
61	EOM	TOMS/EP	Total Ozone Mapping Spectrometer/Earth Probe: the TOMS instrument payload accomplishes the contiguous survey of the Earth's global ozone layer every day. Will be launched by Pegasus. Launch: 05/94	Total Ozone Mapping Spectrometer (TOMS)	955 x 955 km, 99.28 degree inclination	Reference [1]
62	SCIM	TOPSAT	Topographic Satellite: consist of two spacecraft in 560 km polar earth orbit having a small angular separation between the orbit planes. Differential data from the two SARs will be used to generate a terrain map having a height uncertainty of 3 meters in any resolution element of 30 m. Launch 98; mission duration 9 months.	SAR	560x560 polar orbit	Reference [3]
63	EOM	TRMM	Tropical Rainfall Measuring Mission: the purpose is to study the distribution and variability of precipitation and latent heat release over a multi-year data set. TRMM is a climate mission designed to determine the rate of rainfall and the total rainfall between the North and South latitudes of 35 degrees. The primary climate data set is the monthly average rainfall with a spatial resolution of 500 km. - TRMM is an integral part of the NASA Mission to Planet Earth Program. It is a joint mission between NASA and NASDA. Launch from Tanegashima. Launch: 08/97	No detailed information available to the author.	350 x 350 km, 35 degrees inclination	Reference [1]

NO	CATE-GORY	NAME	OBJECTIVES	PAYLOAD/FUNCTIONS	ORBIT	REMARKS
64	SCIM	WIND and POLAR	Two missions within the frame of ISTP/GGS (International Solar Terrestrial Physics Programme/Global Geospace Science). This programme will measure, model and quantitatively assess the processes in the Sun-Earth interaction chain by the use of simultaneous spacecraft placed in complementary orbits. ESA will make contributions to this program by CLUSTER and Japan by GEOTAIL. Launches: WIND 04/94, POLAR 06/94.	No detailed information available to the author.	- WIND in 60 x 250 RE orbit after lunar swing by - POLAR 1.8 x 9 RE polar orbit with apogee near the north pole	Reference [1]
65	SCIM	XTE	X-Ray Timing Explorer: XTE will study a variety of x-ray sources including white dwarfs, accreting neutron stars, black holes, and active galactic nuclei. Measurements will be made over a wide range of photon energies from 2 to 200 keV. Launch: 08/95	• Proportional Counter Array (PCA) • All Sky Monitor (ASM) • High X-Ray Timing Experiment.	600 x 600 km, 23 degrees inclination	Reference [1]

TABLE 2.4: NASA MISSIONS - SPACE DATA SYSTEM ELEMENTS AND OPERATIONS SCENARIOS

This table contains the space data system elements in terms of ground stations, control and data centres including the data links between these facilities. Those mission scenarios which represent interoperation scenarios, i.e. which are the subject of the remaining chapters in this report and of the study work in WPs 2000 and 3000 are underlined.[2] For interpretation of the link designations see Figure 2.1.

NO	NAME	SPACE-GROUND LINK TERMINAL/SYSTEMS		CONTROL CENTRE		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
35	ACE	DSN The s/c carries a 0.6x10exp9 solid state recorder which requires dump time of 2.33 h/day	DSN	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
36	ARIANE Launch Vehicle Support	Bermuda Station: - receiving telemetry (240 kbps): is stripped down to 9.6 kbps and sent to CSG in real-time - performing ranging					(a) EPI-NG-EC for third stage tracking	
37	AXAF	- TDRSS SSA every other orbit for commanding and realtime telemetry downlink	- GN/DSN (Merritt Island and DSN 26 meter subnet) for science and engineering telemetry data playback operations	POCC at MSFC	POCC at MSFC	Only real-time data are transmitted from the SN (i.e. from the s/c via TDRSS) via NASCOM to the MSFC AXAF-S POCC; this means apparently that payload data are transmitted via tape to either the POCC or any data centres.	(a) NPI&PI-NS-NC for platform and payload control (b) N-NG-ND for playback payload data	Source is [1]
38	CONTOUR	DSN (X-band), both 34 and 70 m	DSN (X-band)	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]

[2] The subject of the study requires the consideration of all interoperability scenarios. Therefore not necessarily all agency scenarios are included in the column 'Operation Scenarios'.

NO	NAME	SPACE-GROUND LINK TERMINAL/SYSTEMS		CONTROL CENTRE		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
39	EOS	Here for EOS-AM1. - Command and ranging: TDRSS-SSA and SMA (contingency only) - Telemetry RT and playback: TDRSS-KSA and SSA - Contingency and emergency command and telemetry support: DSN, GN and Wallops	Here for EOS-AM1: - Recorded Science Data: TDRSS-KSA - Direct Access System (DAS): X-band transmission to ground stations	EOS Operations Centre (EOC)	EOS Operations Centre	EOS Data and Information System (EOSDIS)	Both forward and return link data will be formatted consistent with CCSDS standards. (See pages 20 and 26 of Reference [1]) (a) NPI&PI-NS-NC for routine platform and payload control (b) N-NG-NC for platform and payload control in contingency case (c) NPI-NS-ND for payload processing (d) NPI-EG-ED for European data acquisition from NASA payload (e) EPI-NPI-EG-ED for European data acquisition from European payload (f) EPI-NPI-NS-NC-EC for commanding of European payload (g) EPI-NPI-NG/S-ND for NASA data acquisition from European payload Data structures according to CCSDS	Reference [1]
40	EURECA-2	- EURECA commands will be generated by ESOC, routed to JSC and integrated into the overall STS uplink via TDRSS. - EURECA telemetry will be acquired via the STS return link and TDRSS.	No payload ops during release and retrieval	JSC Mission Control Centre with support from ESOC	No payload ops during release and retrieval	No payload ops during release and retrieval	(a) EPI-Shuttle-NS-NC-EC for deployment and retrieval	
41	FAST (SMEX)	Apogee in northern hemisphere: - Poker Flat (prime) - GN and DSN (backup) Apogee in southern hemisphere: - WFF, Poker Flat, GN and DSN	- transportable ground station (WFF) - Kiruna - GN - DSN	Transportable POCC (TPOCC) located at GSFC	TPOCC, probably with planning support from the University of California Science Operations Centre (UCSOC)	- Payload Processing System (PPS) will receive the downlinked data from each ground station - PPs will perform level-zero processing and data distribution to UCSOC - UCSOC will perform science data analysis and distribution	ESA is assumed to fly instruments on FAST and probably also on other satellites of this series; the satellites will transmit instrument data to the ground in S-band; NASA intends to design data structures according to CCSDS Recommendations. (See page 39 of Reference [1]) (a) NPI&PI-NG-NC for platform and payload control (b) EPI-NPI-NG-NC-ECPI for ESA payload commanding (c) EPI-NPI-EG-EC-ED for ESA payload data acquisition	Reference [1]
42	FUSE	- WOTS (S-band) - DSN (S-band), secondary stations - Store and dump mode of data operations is used	- WOTS (S-band) - DSN (S-band), secondary stations	GSFC	GSFC	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]

NO	NAME	SPACE-GROUND LINK TERMINAL/SYSTEMS		CONTROL CENTRE		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
43	GOES	- Goldstone 26 m - Wallops Island/Command and Data Acquisition (WLP/CDA) (NOAA Facility)	- WLP/CDA	NOAA	NOAA	NOAA	(a) NPI&PI-NG-NC for platform and payload control (b) NPI-NG-ND for payload data handling	Reference [1]
44	GRAND TOUR CLUSTER	DSN (S- or X-band)	DSN (S- or X-band)	JPL (or GSFC ?)	JPL (or GSFC ?)	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
45	HESP	- WOTS (CCSDS compatibility is planned)	- WOTS - DSN (as supplement)	GSFC	GSFC	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
46	IRAM	DSN (X-band) (CCSDS compatibility in coding, telemetry and telecommand (COP 1) is planned)	DSN (X-band)	JPL	JPL	Not known, but a specific centre will certainly be established for a mission of this type	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
47	LANDSAT-7	- TDRSS SSA and MA - DSN and Air Force network, and WFF as backup	- TDRSS Ku-band - direct to ground transmission in X-band, in particular for international stations	LANDSAT-7 Mission Operations Centre (MOC)	LANDSAT-7 MOC	- LANDSAT Data and Operations System (LDOS) at the White Sands Complex - LANDSAT-7 Data Handling Facility (DHF) in Sioux Falls - several international data hand-ling facilities	The satellite will transmit instrument data to the ground in X-band; NASA intends to design data structures according to CCSDS Recommendations; also Ku-band and S-band data transmitted via TDRSS will be structured according to CCSDS. (See page 61 of Reference [1]) (a) NPI&PI-NS-NC for platform and payload control (b) NPI&PI-NG-NC for backup (and possibly direct to ground transmission) (c) NPI-EG-ED for direct to ground transmission and acquisition by ESA	Reference [1]
48	MARS BALLOON	As for other Mars missions	As for other Mars missions	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [4]
49	MARS OBSERVER D1 AND D2 PAYLOAD	As for other Mars missions	As for other Mars missions	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [4]

NO	NAME	SPACE-GROUND LINK TERMINAL/SYSTEMS		CONTROL CENTRE		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
50	MESURE	- DSN (X-band, 34 m, if relay satellite available) - DSN (X-band, 34 and 70 m if relay satellite not available)	As for TTC	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [4]
51	NEAR	DSN (X-band, 34 and 70 m)	DSN (X-band, 34 and 70 m)	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
52	NOAA-K,-L,-M	- NOAA CDA stations - DSN (early orbit and contingency) - AFSCN (EO and conting.)	- NOAA CDA stations (S-band)	NOAA Satellite Operations Control Centre at Suitland	NOAA Satellite Operations Control Centre at Suitland	- NOAA Satellite Operations Control Centre at Suitland - possibly others	Will be CCSDS compatible, probably with AOS frame. (Source ?) (a) NPI&PI-NG-NC for platform and payload control (b) NPI-EG-ED for acquisition of payload data by EUMETSAT	Reference [1]
53	NOAA-O,-P,-Q	- NOAA CDA stations - DSN (early orbit and contingency) - AFSCN (EO and conting.)	- NOAA CDA stations (S-band)	NOAA Satellite Operations Control Centre at Suitland	NOAA Satellite Operations Control Centre at Suitland	- NOAA Satellite Operations Control Centre at Suitland - possibly others	(a) NPI&PI-NG-NC for platform and payload control (b) NPI-EG-ED for acquisition of payload data by EUMETSAT	
54	PLUTO FLYBY	DSN (X-band, 34 m and some 70 m coverage)	DSN (X-band, 34 m and some 70 m coverage)	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
55	SeaStar/-SeaWifs	- NASA/Wallops - Orbital Science Corporation (OSC) at Chantilly station (?)	- NASA/Wallops - Orbital Science Corporation (OSC) at Chantilly station (?)	SeaWifs Mission Operation Centre at OSC	SeaWifs Mission Operation Centre at OSC	OSC	(a) NPI&PI-NG-NC for platform and payload control	Reference [1]
56	SOLAR PIONEER	DSN (KA-band, 70 m)	DSN (KA-band, 70 m)	JPL	JPL	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]
57	Space Station (Alpha) Phase 3	TDRSS: - command S-band - telemetry S-band and Ku-band	TDRSS: - command S-band - telemetry S-band and Ku-band	- MCC Houston as prime centre - MCC Kaliningrad as supplement and backup centre	- HOSC at MSFC including a User Science Operation Centre (USOC) - MCC Kaliningrad for Russian payload - appropriate centres for Japanese and European payload	- Payload Data Services System (PDSS) at MSFC - more for international payload	The Space Station (Alpha) Programme command and telemetry data will comply with the CCSDS Recommendation for Advanced Orbiting Systems (AOS) (CCSDS 701.0-B-2). (See page 82 of Reference [1]) (a) NPI&PI-NS-NC for platform and payload control (b) N&EPI-NS-NCPI for payload specific control (c) EPI-USLAB-NS-NCPI-ECPI for ESA payload specific control (d) EPI-EG-ED for direct transmission of ESA payload to ground (e) EPI-ES-ED for transmission of ESA payload data via DRS	Reference [1] The scenario (c) concerns ESA payload in the US laboratory. The scenarios concerning COF are covered under the Columbus programme in line 7.

NO	NAME	SPACE-GROUND LINK TERMINAL/SYSTEMS		CONTROL CENTRE		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
58	SPACELAB	TDRSS (via Shuttle)	TDRSS (via Shuttle); in case of SST KU-band failure various station of the Ground Network (GN) are required to support SPACELAB payload recorder dumps	SPACELAB MCC at JSC	SPACELAB POCC at MSFC	SPACELAB Data Processing Facility (SLDPF) at GSFC	(a) NPI-Shuttle-NS-NCPI for platform control (b) NPI-Shuttle-NS-NCPI for control of NASA payload (c) EPI-Shuttle-NS-NCPI-ECPI for control of ESA payload	Source is [1]
59	SWAS (SMEX)	- Wallops Flight Facility (WFF) - Poker Flat	- Wallops Flight Facility (WFF) - Poker Flat	TPOCC at GSFC. The SMEX TPOCC is a portable, expandable, configerable HW/SW system for the operation of s/c and/or payloads. This new system will perform POCC functions in a workstation environment. The SMEX POCC concept includes multi-mission support.	TPOCC at GSFC supported by the Smithonian Astrophysical Observatory Science Operations Centre (SAOSOC).	The Sensor Data Processing System (SDPF) of Pacor II will receive and perform essentially level-0 processing and distribution to SAOSOC.	(a) NPI&PI-NG-NC for platform and payload control	Reference [1]
60	TIMED-H & -L	- WFF (S-band) - DSN (emergency only)	- WFF (S-band)	TPOCC at GSFC	TPOCC	Level zero processing by the Data Capture Facility at GSFC then forwarded to TSDR (?) for further processing.	All spacecraft data will be in CCSDS format. (See page 101 of Reference [1]) (a) NPI&PI-NG-NC for platform and payload control	Reference [1]
61	TOMS/EP	- DSN - WOTS The s/c will be capable of ensuring the safety of the TOMS instrument autonomously for at least 24 hours without ground contact.	- DSN - WOTS	NIMBUS-7 TOMS Mission Operations Centre (TMOC) at GSFC	TMOC	- TMOC (level zero) - Science Operation Centre Code 916 at GSFC	(a) NPI&PI-NG-NC for platform and payload control	Reference [1]
62	TOPSAT	DSN (S-band)	X-band: - Canberra DSN - Alaska SAR station - McMurdo stations	JPL (?)	JPL (?)	Not known	(a) NPI&PI-NG-NC for platform and payload control	Reference [3]

NO	NAME	SPACE-GROUND LINK TERMINAL/SYSTEMS		CONTROL CENTRE		SCIENCE OR DATA CENTRES	OPERATION SCENARIOS	REMARKS
		PLATFORM	PAYLOAD	PLATFORM	PAYLOAD			
63	TRMM	TDRSS	TDRSS	TRMM MOC at GSFC	TRMM MOC at GSFC	- Sensor Data Processing Facility (SDPF): RT data processing; level zero processing and routing - TRMM Science Data and Information System (TSDIS) at GSFC - Japanese data centre	(a) NPI&PI-NG-NC for platform and payload control	Reference [1] TRMM has adopted CCSDS Recommendations according to TSG 1994 presentation "Cross Support Overview for Future Space Missions" (Stallings/Kaufeler)
64	WIND & POLAR	DSN 26 m	DSN 26 m	Transportable POCC (TPOCC) at GSFC	TPOCC with planning support from Science Planning and Operations Facility (SPOF) at GSFC	- GDCF (?) at GSFC will perform level-0 processing and distribute to Central Data Handling Facility (CDHF); - the CDHF will distribute to users	(a) NPI&PI-NG-NC for platform and payload control	Reference [1]
65	XTE	TDRSS	TDRSS	TPOCC at GSFC	TPOCC at GSFC	- Sensor Data Processing Facility (SDPF): RT DP and Level zero DP and routing (using PACOR)	(a) NPI&PI-NG-NC for platform and payload control	Reference [1]

3.2 THE INTEROP SCENARIOS DERIVED FROM THE TABLES IN CHAPTER 2

Table 3.1 identifies those missions which are candidates for interoperability. This is a sub-set of the missions listed in Tables 2.1 through 2.4. It describes the requirements governing the interoperability scenarios in plain language concerning the space-ground link and the ground-ground link.

TABLE 3.1: ESA AND NASA MISSIONS - REQUIRED SERVICES FOR INTEROPERATION MISSIONS

NO	NAME	SERVICE REQUIREMENTS		REMARKS
		CONCERNING SPACE-GROUND LINK	CONCERNING GROUND-GROUND LINK	
(1) MISSIONS SPONSORED BY ESA				
1	ARIANE 5	OS (b): - Transmission of ESA platform TLM to NASA ground network (Bermuda station) - RNG of ESA s/c	OS (b): - Transmission of TLM and ranging data from NASA ground station (Bermuda) to ESA control centre (Kourou)	
4	ATV	OS (c): - Transmission of ESA platform TLM to Space Station Alpha - Transmission of CMD from Space Station Alpha to ESA platform - Exchange of RNG data between ESA platform and Space Station Alpha (possibly skin radar ranging)	OS (b): - Transmission of TLM from ESA space network (DRS) ground terminal via ESA control centre to Space Station Alpha control centre in Houston	
5	CLUSTER	OS (b): For ESA platform systems: TLM reception, CMD transmission and RNG through Goldstone and Canberra OS (d): For ESA platform and ESA&NASA payload systems: as for OS (b) OS (f): For a specific NASA high rate data payload: routing of TLM from the instrument to the platform data system and then transmission to Goldstone and Canberra.	OSs (b) & (d): - transmission of TLM data from Goldstone and Canberra NDIUs (Network Data Interface Unit; makes DSN stations looking like an ESA station) to ESOC - transmission of CMD data from ESOC to Goldstone and Canberra vie NDIUs - transmission of ranging requests from ESOC to these stations - transmission of RNG data from these stations to ESOC.	
6	COBRAS/ SAMBA	OS (b): As OS(b) for ROSETTA	OS (b): As OS(b) for ROSETTA	

NO	NAME	SERVICE REQUIREMENTS		REMARKS
		CONCERNING SPACE-GROUND LINK	CONCERNING GROUND-GROUND LINK	
7	COLUMBUS PROGRAMME	OS (b), (c) and (d): - Transmission of (S-band) TLM of NASA payload located in COF via DRS to the COLUMBUS Earth Terminal (CET) - CMD transmission for NASA payload in COF from the CET - Voice and video communication of COF via ISSA platform and TDRSS - Transmission of COF TLM via TDRSS to SSCC - CMD transmission from SSCC via TDRSS to COF	OS (c): - Transmission of NASA payload TLM from CET to SSCC and POIC - Transmission of CMD loads from SSCC to CET - Voice and video exchange between European COFCC (at GSOC) and POIC and SSCC.	
8	CTV	OS (c): - Transmission of ESA platform TLM to Space Station Alpha - Transmission of TLM from Space Station Alpha to ESA platform - Exchange of RNG data between ESA platform and Space Station Alpha (possibly skin radar ranging) - Exchange of voice information between ESA platform and Space Station Alpha	OS (b): - Transmission of TLM from ESA space network (DRS) ground terminal via ESA control centre to Space Station Alpha control centre in Houston	
10	ENVISAT	OS (a): As OS (a) for ERS 1/2 OS (e): As OS (e) for ERS 1/2	OS (a): As OS (a) for ERS 1/2	
11	ERS 1/2	OS (a): - Transmission of ESA platform TLM to NASA stations (Wallops, Poker Flat) - CMD transmission from NASA stations (Wallops, Poker Flat) to ESA platform - RNG of ESA s/c from NASA stations (Wallops, Poker Flat) OS (e): - Transmission of ESA payload data to NASA or NOAA stations (e.g. Fairbanks)	OS (a): - transmission of TLM data from NASA stations (Wallops, Poker Flat) to ESOC - transmission of CMD data from ESOC to NASA stations (Wallops, Poker Flat) - transmission of RNG data from NASA stations (Wallops, Poker Flat) to ESOC.	
12	EURECA MISSIONS	OS (a): - Transmission of ESA platform TLM to Shuttle data handling system (via the Payload Interrogator link) - CMD transmission from Shuttle data handling system to ESA platform (via the Payload Interrogator Link)	OS (a): - transmission of TLM data from NASA Shuttle control centre (via NASCOM) to ESOC - transmission of CMD data from ESOC (via NASCOM) to NASA Shuttle control centre - transmission of Shuttle state vector from NASA Shuttle control centre to ESOC - transmission of ESA's Eureca RGN data to the NASA Shuttle control centre	
14	HUBBLE	Ongoing mission, therefore not considered for the time being. Later on a description of the ESA-NASA interfaces may be added for comparison reasons.	Ongoing mission, therefore not considered for the time being. Later on a description of the ESA-NASA interfaces may be added for comparison reasons.	
15	HUYGENS	OS (a) - Transmission of Huygens platform TLM to (? to Cassini data handling system and to ?) DSN - CMD transmission from DSN to (? Cassini data handling system and to ?) Huygens platform. OS (b) - Transmission of Huygens platform and payload TLM to Cassini and to DSN - Transmission of Huygens CMD from DSN stations to Cassini and to Huygens platform and payload	OS (b): - Transmission of quick look TLM between JPL platform and payload control centre and ESOC POCC - Transmission of CMD from ESOC POCC and JPL	
16	INTEGRAL	OS (b): - Transmission of ESA platform and payload TLM to DSN stations (probably Goldstone and Canberra) - CMD transmission from DSN stations to ESA platform and payload - RNG of ESA s/c from DSN stations.	OS (b): - transmission of TLM data from DSN (or NASCOM) to ESOC - transmission of CMD data from ESOC to DSN (possibly via NASCOM) - transmission of RNG data from DSN to ESOC.	
17	INTER-MARSNET	OS (a)and (b): As OS(b) for ROSETTA	OS (a): As OS(b) for ROSETTA	
18	ISO	OS (b): As OS(b) for ROSETTA (Goldstone support only)	OS (b): As OS(b) for ROSETTA (Goldstone support only)	

NO	NAME	SERVICE REQUIREMENTS CONCERNING SPACE-GROUND LINK	 CONCERNING GROUND-GROUND LINK	REMARKS
19	METEOSAT SECOND GENERATION	OS (c): - Transmission of ESA/EUMETSAT platform and payload TLM to NOAA stations - CMD transmission from NOAA stations to ESA/EUMETSAT platform and payload - RNG of ESA/EUMETSAT s/c from NOAA stations	No interop requirements	
20	METEOSAT	OS (c): - Transmission of ESA platform and payload TLM to NOAA ground station - CMD transmission from NOAA ground station to ESA platform and payload - RNG of ESA s/c from NOAA station.	No interop requirements	
21	METOP	OS (a): As OS (a) for ERS 1/2 OS (e): As OS (e) for ERS 1/2 OS (f): - Communication of NOAA payload with ESA/EUMETSAT platform data handling system	OS (a): As OS (a) for ERS 1/2, however host in Europe is EUMETSAT control centre instead of ESOC	
22	MORO	OS (a) and (b): As OS(b) for ROSETTA	OS (a): As OS(b) for ROSETTA	
23	ROSETTA	OS (b): - Transmission of ESA platform and ESA&NASA payload TLM to DSN stations (probably Goldstone and Canberra) - CMD transmission from DSN stations to ESA platform and ESA&NASA payload - RNG of ESA s/c from DSN stations.	OS (b): - transmission of TLM data between DSN (or NASCOM) and ESOC - transmission of CMD data from ESOC to DSN (possibly via NASCOM) - transmission of RNG data from DSN to ESOC.	
24	SOHO	OS (a): - Transmission of ESA platform and ESA&NASA payload TLM to DSN 26 m stations - CMD transmission from DSN 26 m stations to ESA platform and ESA&NASA payload - RNG of ESA s/c from DSN stations. OS (b): - Communication of NASA payload with ESA platform data handling system	OS (c): - transmission of ESA payload data from data processing facilities at GSFC to ESA or investigators data handling centres (neither in real-time nor in near real-time)	
25	SPACELAB MISSIONS	OS (a) and (b): - Transmission of ESA platform and payload TLM to Shuttle data handling system - CMD transmission from Shuttle data handling system to ESA platform and payload	OS (b): - Transmission of TLM from NASA POCC (at MSFC) to European POCC (GSOC) - Transmission of CMD loads from European POCC (GSOC) to NASA POCC (MSFC)	
27	STEP	OS (a): - Transmission of ESA platform and ESA&NASA payload TLM to DSN stations (probably Goldstone and Canberra) - CMD transmission from DSN stations to ESA platform and ESA&NASA payload - RNG of ESA s/c from DSN stations. OS (b): - Communication of NASA payload with ESA platform data handling system	No interop requirements	
28	ULYSSES	Ongoing mission, therefore not considered for the time being. Later on a description of the ESA-NASA interfaces may be added for comparison reasons.	Ongoing mission, therefore not considered for the time being. Later on a description of the ESA-NASA interfaces may be added for comparison reasons.	

NO	NAME	SERVICE REQUIREMENTS		REMARKS
		CONCERNING SPACE-GROUND LINK	CONCERNING GROUND-GROUND LINK	
(2) MISSIONS SPONSORED BY NASA				
39	EOS	OS (d): - Transmission of NASA payload TLM to the ESA ground network (Kiruna, Maspalomas, Fucino and others) OS (e) and (g): - Transmission of ESA payload TLM to NASA platform data handling system OS (f): - Transmission of ESA CMD from NASA platform data handling system to ESA payload	OS (f): - Transmission of CMD for European payload from (e.g.) ESOC to NASA EOS operations centre	
41	FAST	OS (b): - Transmission of CMD from NASA platform data handling system to ESA payload OS (c): - Transmission of ESA payload TLM to NASA platform data handling system	OS (b): - Transmission of CMD for European payload from (e.g.) ESOC to NASA TPOCC at GSFC	
47	LANDSAT 7	OS (c): Transmission of NASA payload TLM to ESA ground network (stations such as Kiruna, Maspalomas, Fucino)	No interop requirements	
52	NOAA-K,-L,-M	OS (b): As for Landsat OS (c)	No interop requirements	
53	NOAA-O,-P,-Q	OS (b): As for Landsat OS (c)	No interop requirements	
57	SPACE STA-TION	OS (c): - Transmission of ESA payload TLM to US Laboratory data handling system - CMD transmission from US Laboratory data handling system to ESA payload.	OS (c): - Transmission of TLM from NASA POCC (at MSFC) to European POCC (GSOC) - Transmission of CMD loads from European POCC (GSOC) to NASA POCC (MSFC) - Voice exchange between European POCC (GSOC) and NASA POCC (MSFC) This is the same as OS (c) for the Columbus Programme	
58	SPACELAB	OS (c): - Transmission of ESA payload TLM to Spacelab data handling system - CMD transmission from Spacelab data handling system to ESA payload	OS (c): - Transmission of TLM from NASA POCC (at MSFC) to European POCC (GSOC) - Transmission of CMD loads from European POCC (GSOC) to NASA POCC (MSFC) This is the same as OS (b) for European Spacelab missions	These are NASA Spacelab missions unlike European Spacelab missions registered in line 25.

TABLE 4.1: CONVENTIONAL TELEMETRY SERVICES

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
LAYER E: SPACE MISSION APPLICATION LAYER			
T-E1	Source Packet Formatting Service	Input: Packet Data Field; length in octets; APID Function: Create Source Packet, including Source Sequence Count and Packet Data Length Output: Source Packet Management: Maximum packet length	Input: Source Packet Function: Extracts Packet Data Field and delivers to sink application(s) indicated by APID in header Output: Packet Data Field; sequence quality Management: APID routing
T-E2	Privately Defined Data Formatting Service	Input: A fixed-length, octet aligned data unit Function: Accept privately defined data unit; optionally, accept or provide values for the flag and First Header Pointer of the Transfer Frame; pass a PDD transfer request primitive to the layer below Output: Octet aligned PDD; optionally flag and FHP data Management: Addressing information, fixed legnth of PDD units, timing, latency, flow control	Input: PDD units Function: Accept PDD units; extract PDD units; optionally extract flag and FHP fields; deliver to application entity Output: PDD units Management: PDD units and related data routing
T-E3	Frame Secondary Header Formatting Service	Input: FSH Data Field; optionally VCID Function: Create FSH, including FSH header Output: FSH Management: Fixed length of FSH; FSH Version Number; valid VCIDs	Input: FSH Function: Extracts FSH Data Field and delivers to sink application(s) indicated by System Management Output: FSH Data Field Management: FSH Data Field routing
T-E4	Operational Control Field Formatting Service	Input: OCF report value; OCF report type; optionally VCID Function: Create OCF Output: OCF Management: Valid VCIDs	Input: OCF Function: Extracts OCF report value and delivers to sink application(s) indicated by System Management Output: OCF report value; sequence quality Management: OCF report value routing
LAYER D: SPACE TRANSFER LAYER			
T-D1	Packet Transport Service	Input: Source Packet; APID; Packet Length Field Function: (i) Multiplex Packets from one or more sources (each with unique APID (ii) Optionally break Packets into CCSDS Source Packet Segments (iii) block these Packets/Segments into VC_Frame Data Field (iv) Set Flags and First Header Pointer Output: Frame Data Field; First Header Pointer; Flags Management: Length of Frame Data Field; Segment length	Input: Frame Data Field; First Header Pointer; Flags Function: De-block; concatenate; de-multiplex Packets/Segments from Frame Data Field; optionally: reassemble Source Packet Segments into Source Packets Output: Source Packet; Sequence-Flag plus VC-Count; Quality_Flag Management: Length of Frame Data Field

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
T-D2	Privately Defined Data Service	Input: Fixed-length Privately Defined Data units; Status Fields Function: Create and number a VC_Frame; insert PDD into Frame Data Field and status fields into First Header Pointer field and flag fields Output: VC_Frame Management: Which VCs carry PDD; fixed length of PDD; presence and length of Frame Secondary Header on the VC	Input: VC_Frame Function: Extract Frame Data Field, First Header Pointer and flags Output: Deliver extracted fields with VC_Count and Sequence_Flag Management: Routing for VC; fixed length of PDD; presence and length of Frame Secondary Header on the VC
T-D3	Virtual Channel Frame Secondary Header Service	Input: Fixed-length Frame Secondary Header Function: Synchronously insert FSH into VC_Frame Output: VC_Frame with VC-Frame Secondary Header	Input: VC with VC-Frame Secondary Header Function: extract and deliver VC Frame Secondary Header Output: VC-Frame Secondary Header; VC_Count; Sequence_Flag Note: This service is mutually exclusive with T-C2 (Master Channel Frame Secondary Header Service)
T-D4	Virtual Channel Operational Control Field Service	Input: Fixed-length Operational Control Field Function: Synchronously insert OCF into VC_Frame Output: VC_Frame with VC Operational Control Field	Input: VC Frame with VC Operational Control Field Function: extract and deliver VC Operational Control Field Output: VC Operational Control Field; VC_Count; Sequence_Flag Note: This service is mutually exclusive with T-C3 (Master Channel Operational Control Field Service)
LAYER C: VIRTUAL CHANNEL ACCESS LAYER			
T-C1	Virtual Channel Frame Service	Input: VC_Frames from various Virtual Channels Function: - Multiplex VC_Frames; - add SCID and MC_Count to Frame Header; - optionally, insert fill frames to maintain synchronous flow of frames on the Master Channel; - optionally, add Frame Error Control Field Output: Synchronous stream of sequentially numbered MC_Frames, possibly with space reserved for Frame Secondary Header or Operational Control Field (see services C2 and C3)	Input: Stream of numbered MC_Frames Function: - De-multiplex VC_Frames; - optionally, remove fill frames; - optionally, check Frame Error Control Field Output: VC_Frames; MC sequence quality
T-C2	Master Channel Frame Secondary Header Service	Input: Fixed-length Frame Secondary Header; MC_Frame from service C1 Function: Synchronously insert Frame Secondary Header into MC_Frame Output: MC_Frame including MC Frame Secondary Header Function:	Input: MC_Frame Function: extract and deliver MC Frame Secondary Header Output: MC Frame Secondary Header; MC_Count Notes: (i) This service is mutually exclusive with D3 (VC Frame Secondary Header service) (ii) The on-board data source providing the FSH must make a value available for each MC_Frame. It is the responsibility of each implementation (i.e. each spacecraft) to assure that the timing requirements for the FSH are met, and that the time of measurement of data carried in the FSH can be determined.

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
T-C3	Master Channel Operational Control Field Service	Input: Fixed length Operational Control Field; MC_Frame from services C1 or C2 Function: Synchronously insert Operational Control Field into MC_Frame Output: MC_Frame with MC Operational Control Field	Input: MC_Frame Function: extract and deliver MC Operational Control Field Output: MC Operational Control Field; MC_Count Notes: (i) This service is mutually exclusive with D4 (Virtual Channel Operational Control Field Service) (ii) The on-board data source providing the OCF must make a value available for each MC_Frame. It is the responsibility of each implementation (i.e. each spacecraft) to assure that the timing requirements for the OCF are met, and that the time of measurement of data carried in the OCF can be determined.
LAYER B: CHANNEL ACCESS LAYER			
T-B1	Service to layer above	Input: Fixed-length Transfer Frame Function: - Add synch marker: - optionally, apply RS code - optionally, apply randomization - optionally, apply convolutional code Output: Synchronous stream of channel symbols Management: Frame length, and which, if any, of RS, randomization, or convolutional coding are used (plus parameters, e.g. RS interleaving depth)	Input: Synchronous stream of channel symbols Function: Frame sync and decoding/de-randomizing Output: Corrected Transfer Frame and/or quality indication Management: Frame length, and which, if any, of RS, randomization, or convolutional coding are used (plus parameters)
T-B2	Service assumed from layer below	Physical Access Service	
LAYER A: PHYSICAL ACCESS LAYER			
T-A1	Physical Access Service	Input: Synchronous stream of channel symbols Function: Modulates RF Output: Modulated RF	Input: Modulated RF Function: De-modulates RF Output: Synchronous stream of channel symbols

TABLE 4.2: TELECOMMAND SERVICES

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
LAYER B: DATA ROUTING LAYER			
C-B1	Segmentation Layer Services	**INPUT:** From the Packetization layer or other layer above: (a) Transportable TC User Data Units (e.g., TC Packets) which are to be routed to the spacecraft. The length of the TC User Data Unit is unconstrained; however, if they are TC Packets, then each will have a maximum length of 65542 octets. (b) Control instructions which are required in order to transfer the user data structures to the spacecraft. Those control instructions specifying delivery priority are read and processed by the Segmentation layer and establish the multiplexing hierarchy within this layer. Other control instructions (e.g., directives to abort specific commands) are passed through to the layer below. NOTE: The abstract content and concrete format of the control instructions are not presently specified and remain an item for potential future extension. From the Transfer layer below: (c) Information describing the status of transfer of TC Frame Data Units through a given Virtual Channel. **FUNCTIONS:** (a) Assigns individual TC User Data Units to particular Multiplexer Access Points (MAPs) for routing to the spacecraft through a Virtual Channel (VC) provided by the Transfer layer. (b) Breaks or aggregates the TC User Data Units into pieces which are compatible with insertion into the data field of the TC Frame Data Unit. (c) Optionally labels each piece with sequence control and MAP identification information to create a TC Segment. The TC Segment or the piece from (b), if the Segment Header is not used, becomes the TC Frame Data Unit. (d) Multiplexes TC Frame Data Units from different MAPs together onto one Virtual Channel for flow control purposes. (e) Monitors the process of transferring TC Frame Data Units through Virtual Channels by the layers below, and maintains cognizance of the status and availability of particular Virtual Channels. **OUTPUT:** To the Packetization layer or other layer above: (a) Information describing the status of transfer of TC User Data Units. To the Transfer layer below: (b) User data structures which have been formed into TC Frame Data Units. (c) Control instructions, possibly passed through from the layer above.	**INPUT:** From the Packetization layer or other layer above: (a) Information concerning the ability of the higher layer to accept more data. From the Transfer layer below: (b) TC Frame Data Units in sequence and complete, without omission or duplication (if sent as Type-A Frames). **FUNCTIONS:** (a) Receives TC Frame Data Units from the Transfer layer, delivered on individual Virtual Channels. (b) Sorts TC Frame Data Units associated with individual VCs according to their MAP identifier and reassembles the Segments associated with a particular MAP to reconstruct the TC User Data Unit. (c) Determines when all TC Segments associated with a particular TC User Data Unit have been received correctly. (d) Extracts the TC Packets. (e) Passes the reconstructed TC User Data Units to the Packetization layer or other higher layer. **OUTPUT:** To the Packetization layer or other layer above: (a) Reconstructed User Data Units. To the Transfer layer below: (b) Information concerning the ability of the Segmentation layer to accept more data.

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
C-B2	Transfer Layer Services	**INPUT:** From the Segmentation layer above: (a) TC Frame Data Units. (b) Control Instructions, Management Directives and Data Transfer Requests for the FOP. From the receiving end of the Transfer layer: (c) Information concerning the status of receipt of individual TC Frames, formatted into a Command Link Control Word (CLCW) and extracted from the Telemetry Transfer Frame or the Virtual Channel Data Unit. From the Coding layer below: (d) Status of the physical channel. **FUNCTIONS:** (a) Encapsulates TC Frame Data Units into TC Transfer Frames. (b) Translates control instructions received from layers above into the appropriate set of operational procedures to be used to transfer the TC Transfer Frames to the spacecraft, including selection of the correct mode (Acceptance Test or Bypass) of the Command Operation Procedure (COP). (c) Creates Control Command TC Transfer Frames for transmission to the receiving end of the layer in order to control the Frame Acceptance and Reporting Mechanism (FARM). (d) Supervises the transfer of TC Transfer Frames to the receiving end by executing a Frame Operation Procedure (FOP) in accordance with the selected mode of the COP. (e) Retransmits TC Frames as required to rectify channel-induced errors. (f) Responds to control instructions from layers above to abort command transmission by issuing the appropriate set of control instructions to the layer below.	**INPUT:** From the Segmentation layer above: (a) Information defining the ability of the Segmentation layer to accept more data (optional). From the sending end of the Transfer layer: (b) Control Command TC Transfer Frames which contain instructions defining how the data-carrying TC Transfer Frames are to be processed. From the Coding layer below: (c) "Clean" octets of decoded TC data. (Note: only correct data, which have passed the decoder quality check, will normally be received.) (d) "Data Start" signal (indication of the start of the first valid octet of TC data). (e) "Data Stop" signal (indication of the last valid octet of TC data). (Note: trailing octets of Fill Data could be present just before the Data Stop signal is received.) (f) Control information describing the status of the physical channel (e.g., rf and bit synchronization). **FUNCTIONS:** (a) Responds to Control Command TC Transfer Frames received from the sending end of the layer. (b) Performs the Frame Validation Check Procedure for all TC Transfer Frames and the frame acceptance checks of the Frame Acceptance and Reporting Mechanism for Type-A Frames. (c) Creates reports (CLCWs) to the sending end describing the status of TC Transfer Frame acceptance. (d) Processes TC Transfer Frames which have been retransmitted as required to rectify channel-induced errors. (e) Extracts TC Frame Data Units. (f) Passes the extracted TC Frame Data Units to the Segmentation layer. (g) Responds to control instructions from layers below to abort command transmission by ceasing the processing of the current TC Transfer Frame, and awaiting new control instructions.

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
		OUTPUT: To the Segmentation layer above: (a) Status of the data routing process, including the progress of delivering individual TC Frame Data Units and the availability of Virtual Channels. To the receiving end of the Transfer layer: (b) "Control Command" TC Transfer Frames, which instruct the receiving end how to accept and report the received frames. To the Coding layer below: (c) Buffers of TC data bits containing protocol data units from the TC Transfer layer (i.e., one or more TC Transfer Frames). (d) Control instructions defining the operational procedures to be used to transmit the buffer of bits to the spacecraft.	**OUTPUT:** To the Segmentation layer above: (a) TC Frame Data Units which have been extracted from TC Transfer Frames that passed the validation and, optionally, the acceptance tests. To the sending end of the Transfer layer: (b) CLCWs which will be utilized by the FOP to control the transmission of additional TC Transfer Frames, or the retransmission of previously sent frames, in accordance with the rules of the COP To the Coding layer below: None.
LAYER A: CHANNEL ACCESS AND PHYSICAL ACCESS LAYER			
C-A1	Coding Layer Services	**INPUT:** From the layer above: (a) "Input Data" from the Data Routing Service, to be included in a single CLTU. (b) Control instructions. From the layer below: (c) Status of the physical telecommand channel (i.e., report from the Physical layer) **FUNCTIONS:** (a) Encodes the "Input Data" into TC Codeblocks, adding fill as necessary to complete the last codeblock of the CLTU. (b) Encapsulates the TC Codeblocks into CLTUs by adding Start and Tail Sequences.	**INPUT:** From the layer below: (a) Synchronized detected "dirty" symbol stream (with possible errors if hard-decision decoding is used). (b) Symbol clock (if required). (c) Control information and status (e.g., physical telecommand channel active or inactive). **FUNCTIONS:** (a) Permits the resolution of the sense of "1" and "0" in the incoming stream of dirty symbols, if not already provided by modulation techniques within the layer below. (b) Detects the CLTU Start sequence which provides decoder synchronization for the first codeblock; subsequent codeblocks are automatically synchronized by being contiguous. Signals the start of valid TC data. (c) Within the capability of the decoding algorithm, makes an estimate to determine if an error has probably occurred within the TC Codeblock. (d) Within the capability of the decoding algorithm, optionally makes an estimate of the correct value of the information bits if errors are suspected to have occurred within the group of symbols that correspond to one TC Codeblock, and continues decoding. (e) If a TC Codeblock is encountered which is sufficiently likely to contain a detected or uncorrectable error, declares a codeblock error, leaves the DECODE state, enters the SEARCH state and ceases to output further data. Signals the stop of valid TC data. (f) If the Physical layer signals loss of modulation, leaves the DECODE state, enters the INACTIVE state, ceases to output further data, and signals the stop of valid TC data. (g) Informs the layer above of status of the Channel Service.

NO	SERVICE	SENDING END CHARACTERISTICS	RECEIVING END CHARACTERISTICS
		OUTPUT: To the layer above: (a) Status of the physical telecommand channel. To the layer below: (b) Command Link Transmission Units (CLTUs). (c) Control instructions.	**OUTPUT:** To the layer above: (a) "Clean" decoded TC data from each codeblock which have passed the decoder quality check. May include fill from last codeblock of CLTU. (b) Decode Status, indicating start, continuity, and end of valid TC data. (c) Control information describing status of the physical telecommand channel (e.g., RF and bit synchronization).
C-A2	Physical Layer Services	**INPUT:** From the layer above: (a) Buffers of bits corresponding to a CLTU. (b) Control information. **FUNCTIONS:** (a) Establishes the physical radio frequency path to the spacecraft using the unmodulated carrier. (b) Radiates a buffer of data bits serially according to the PLOP requested by the layer above. **OUTPUT:** To the layer above: (a) Status of the physical telecommand channel To the receiving end of the layer: (b) Modulated radio frequency waveforms, radiated as described in Reference [5].	**INPUT:** From the sending end of the layer: (a) Modulated radio frequency waveforms which have been radiated by a transmitting station. **FUNCTIONS:** (a) Receives and detects the modulated carrier/subcarrier. (b) Performs demodulation and symbol synchronization. (c) Determines the state of the physical telecommand channel (CHANNEL ACTIVE or CHANNEL INACTIVE.) (d) Performs symbol detection (hard decisions or quantized, soft decisions.) (e) Informs the layer above of status of the Physical layer. **OUTPUT:** To the layer above: (a) Synchronized detected "dirty" symbol stream. (b) Symbol clock (if required). (c) Channel Active (modulated carrier/subcarrier present); used by layer above to select between Inactive and Search states, to validate the Decode state and in some cases to initiate inter-layer control instructions. (d) Status of the RF lock and bit synchronization processes.

TABLE 4.1: OVERVIEW OF ESA SPACE DATA SYSTEM FACILITIES

FACILITY	FUNCTIONS	LOCATIONS
Ground Station Network	- Telemetry Acquisition - Telecommand Operations - Tracking Operations	Kourou Diane Malindi Perth Maspalomas Villafranca 1 - 3 Odenwald 1 - 4 Redu Salmijaervi Transportable Station ESOC
Ground Communications Infrastructure	- Two way data and voice connections between ground stations and control centres (OPSNET) - General purpose communications Network of the agency (ESANET)	Multiple nodes at various locations
Operations Control Centres	- Mission planning - Mission control and execution - Mission products handling - Man/machine interface to mission control team	OCC Darmstadt MOCC Darmstadt ECS Redu IUE Villafranca
Computer and Software Systems	- Real-time and/or near real-time monitoring and control - Off-line computing tasks, e.g. mission analysis, flight dynamics, s/c performance evaluation - Data disposition/distribution - Simulations - Archiving of raw telemetry, auxiliary and processed data	ESOC Darmstadt ESRIN Frascati ESTEC Noordwijk ESA HQ Paris Villafranca Redu

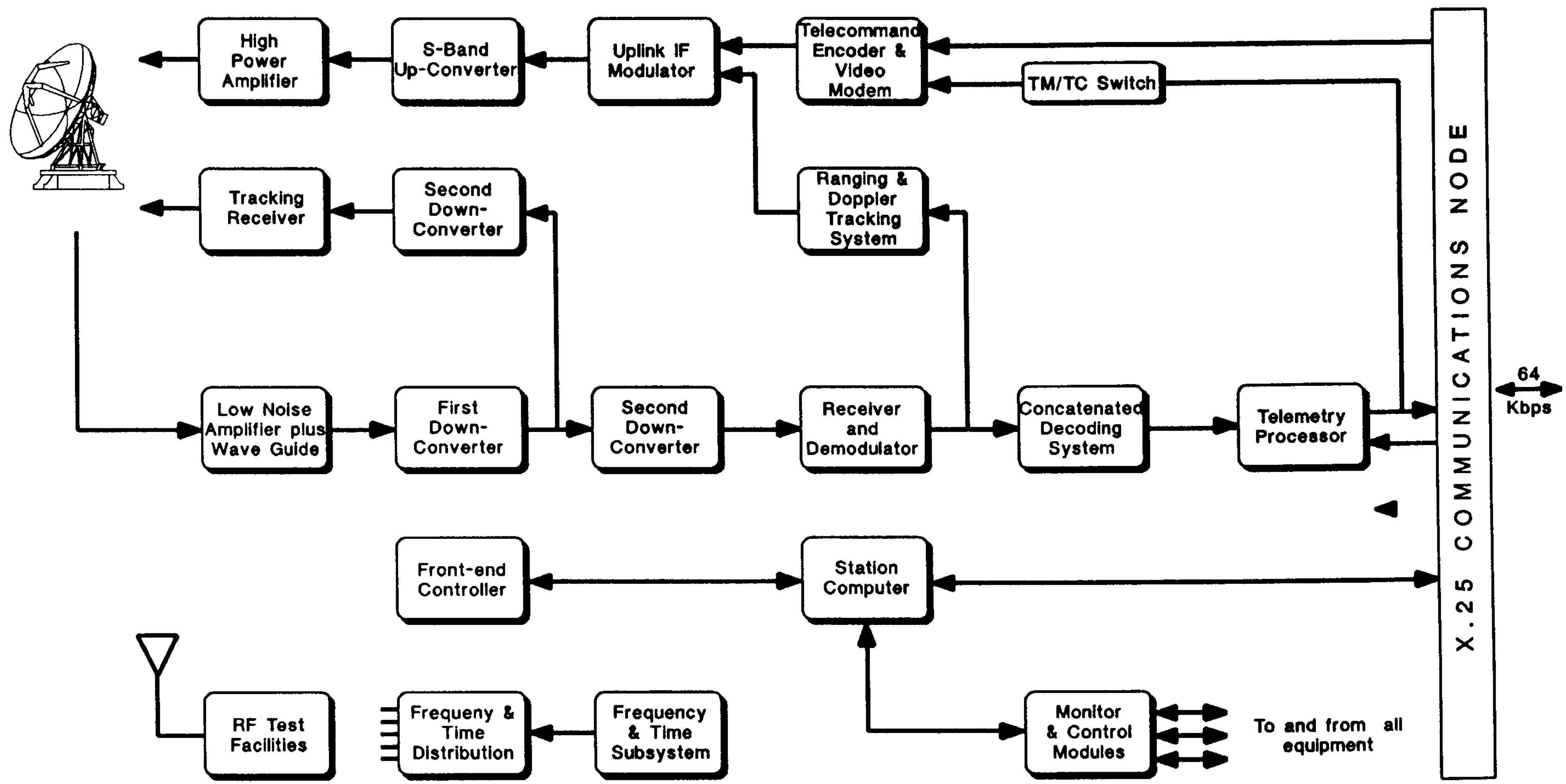

FIGURE 4.1: ESA GENERAL PURPOSE GROUND STATION BLOCK DIAGRAM

TABLE 4.2: CHARACTERISTICS OF ESA GENERAL PURPOSE GROUND STATIONS

	Kourou (Diane)	Perth	Maspalomas	Malindi	Transportable
Antenna Diameter (m)	15			10	5.5
Downlink Frequencies (MHz)	2200-2300 8400-8500			2200-2290	2200-2300
Downlink Polarization	any				
Telemetry Modulation	PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM PCM(SPL)/PM BPSK, QPSK			PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM PCM(SPL)/PM	PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM PCM(SPL)/PM BPSK, QPSK
Telemetry Decoding	CDS2			Convol.Decoding planned 95	Convol.Decoding
Telemetry Processor	Mk III	Mk II/III	Mk III	Mk II	
Uplink Frequency	2025-2120				
Uplink Polarization	RHC/LHC				
Telecommand Modulation	PCM(NRZ)/PSK/PM PCM(SPL)/PSK-AM/PM				
Telecommand Encoder/Controller	Mk IIA				
Ranging/Doppler Tracking	MPTS			Tone Ranging	
Communications Node	ISS30			ECOM25	DYNATEK X.25
Function/Project	LEOP, Ulysses 94/95	LEOP, planned for XMM 1999	Has been used for EURECA and is used for ERS1	LEOP	LEOP, Back-up

TABLE 4.3: CHARACTERISTICS OF ESA MISSION DEDICATED GROUND STATIONS 1

	Odenwald-1 (DATTS)	Odenwald-2	Odenwald-3	Odenwald-4	Villafranca-1	Villafranca-2	Villafranca-3
Antenna Diameter (m)	15		13.5	10	15		12
Downlink Frequencies (MHz)	1670-1700	2200-2300	1670-1700 2242-2250	2200-2290 2242-2250	2218-2250	2200-2300	4188-4201
Downlink Polarization	linear	any	linear		RHC/LHC	any	LHC
Telemetry Modulation	PCM(NRZ)/PM PCM(SPL)/PM PCM(SPL)/PSK/PM	PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM PCM(SPL)/PM	PCM(SPL)/PSK/PM		PCM(SPL)/PM	PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM PCM(SPL)/PM BPSK, QPSK	PCM(SPL)/PSK/PM
Telemetry Decoding	not available	CDS2 (for Cluster)	not available		Convolutional (special to IUE)	CDS2	not available
Telemetry Processor	Mk II plus some Meteosat specials	Post Mk III	Mk II plus some Meteosat specials	Mk II	Frame synchronizer and computer interface	Mk III	Mk II
Uplink Frequency	2089, 2101.5, 2105	2025-2120	2098-2107	2098-2110	149	2025-2120	6415-6427
Uplink Polarization	linear	RHC/LHC	linear		RHC/LHC		RHC
Telecommand Modulation	PCM(SPL)/PSK-AM/FM PCM(SPL)/PSK-AM/PM	PCM(NRZ)/PSK/PM	PCM(NRZ)/PSK/FM PCM(NRZ)/PSK/AM		PCM(SPL)/FSK-AM/PM	PCM(NRZ)/PSK/PM PCM(SPL)/PSK-AM/PM	PCM(SPL)/PSK-AM/FM/PM
Telecommand Encoder/Controller	Mk II				IUE special	Mk III (?) and Mk II	Mk II and Mk I
Ranging/Doppler Tracking	Meteosat specific	MPTS	Spread Spectrum		not available	MPTS	Tone Ranging
Communications Node	COMMET, DPS 25	DPS 25	COMMET, DPS 25		not available	DPS 25	
Function/Project	Meteosat	Cluster	Meteosat	Meteosat	IUE	ISO also planned for Integral in 2000, plus back-up	MARECS-B

TABLE 4.4: CHARACTERISTICS OF ESA MISSION DEDICATED GROUND STATIONS 2

	Kiruna	Redu (TM-1,2,3,6)	Redu (TMS-1)	Redu (RG-1)	Redu	Redu Cluster
Antenna Diameter (m)	15	4.5	13.5	4.5	4.5	15
Downlink Frequencies (MHz)	2200-2300 8050-8500	10954-11700	10950-11800	10954-11700	4188-4201	2200-2300
Downlink Polarization	any (S-band) RHC/LHC (X-band)	linear			LHC	any
Telemetry Modulation	PCM(SPL)/PSK/PM (only for ERS-1 sub-carrier and bit rate)	PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM			PCM(SPL)/PSK/PM	PCM(NRZ)/PSK/PM PCM(SPL)/PSK/PM PCM(SPL)/PM
Telemetry Decoding	not available					CDS2
Telemetry Processor	Mk II					Post Mk III
Uplink Frequency	2025-2120	not available	14000-14500		not available	2025-2120
Uplink Polarization	RHC/LHC	not available	linear		RHC	RHC/LHC
Telecommand Modulation	PCM(NRZ)/PSK/PM	not available				PCM(NRZ)/PSK/PM
Telecommand Encoder/Controller	Mk II	not available				Mk II, post Mk III (?)
Ranging/Doppler Tracking	MPTS	not available		Tone Ranging	not available	MPTS
Communications Node	DPS 25	ECOM 25	not available	ECOM 25		DPS 25
Function/Project	ERS-1, ERS-2, ENVISAT	ECS			MARECS	CLUSTER

TABLE 4.6: OVERVIEW OF NASA SPACE DATA SYSTEM FACILITIES

FACILITY	FUNCTIONS	LOCATIONS
Ground Station Network	- Telemetry Acquisition - Telecommand Operations - Tracking Operations	STDN: Merrit Island, Bermuda, Dakar Wallops Flight Facility: Wallops, Poker Flat, White Sands, McMurdo, Transportable Western Aeronaut. Test Range: Dryden Flight Research Centre, Ames Research Centre, Crows Landing Fac. Deep Space Network: Goldstone, Madrid, Canberra
Ground Communications Infrastructure	- Two way data and voice connections between ground stations and control centres - General purpose communications Network of the agency	NASCOM PSCN
Operations Control Centres	- Mission planning - Mission control and execution - Mission products handling - Man/machine interface to mission control team	GSFC MSFC JSC JPL others tbd.
Computer and Software Systems	- Real-time and/or near real-time monitoring and control - Off-line computing tasks, e.g. mission analysis, flight dynamics, s/c performance evaluation - Data disposition/distribution - Simulations - Archiving of raw telemetry, auxiliary and processed data	- Information Processing Division at GSFC - Signal Processing Centres for DSN others tbd.

TABLE 4.7: MISSION ASSIGNMENT OF NASA SPACE AND GROUND NETWORK

Mission Type	Space Network (SN)	Ground Networks (GN)			
		Deep Space Network	Satellite Tracking and Data Network	Wallops Flight Facility	Western Aeronautical Test Range
Suborbital	Limited support		Limited support	Primary support for balloons, sounding rockets and aircraft	Primary support for aircraft
Earth Orbital	Primary support for low earth orbiting s/c	Primary support for highly elliptically orbiting s/c	Primary or emergency support to launches and some low earth orbiting s/c; backup to SN	Limited support to launches and some earth orbiting s/c	
Shuttle	Primary support	Emergency backup	Support to launch, orbital path, landing at KSC and emergency backup	Support to downrange launch	Landing support at Edwards Airforce Base
Interplanetary		Primary support			
Radio Science		Primary support		VLBI support	

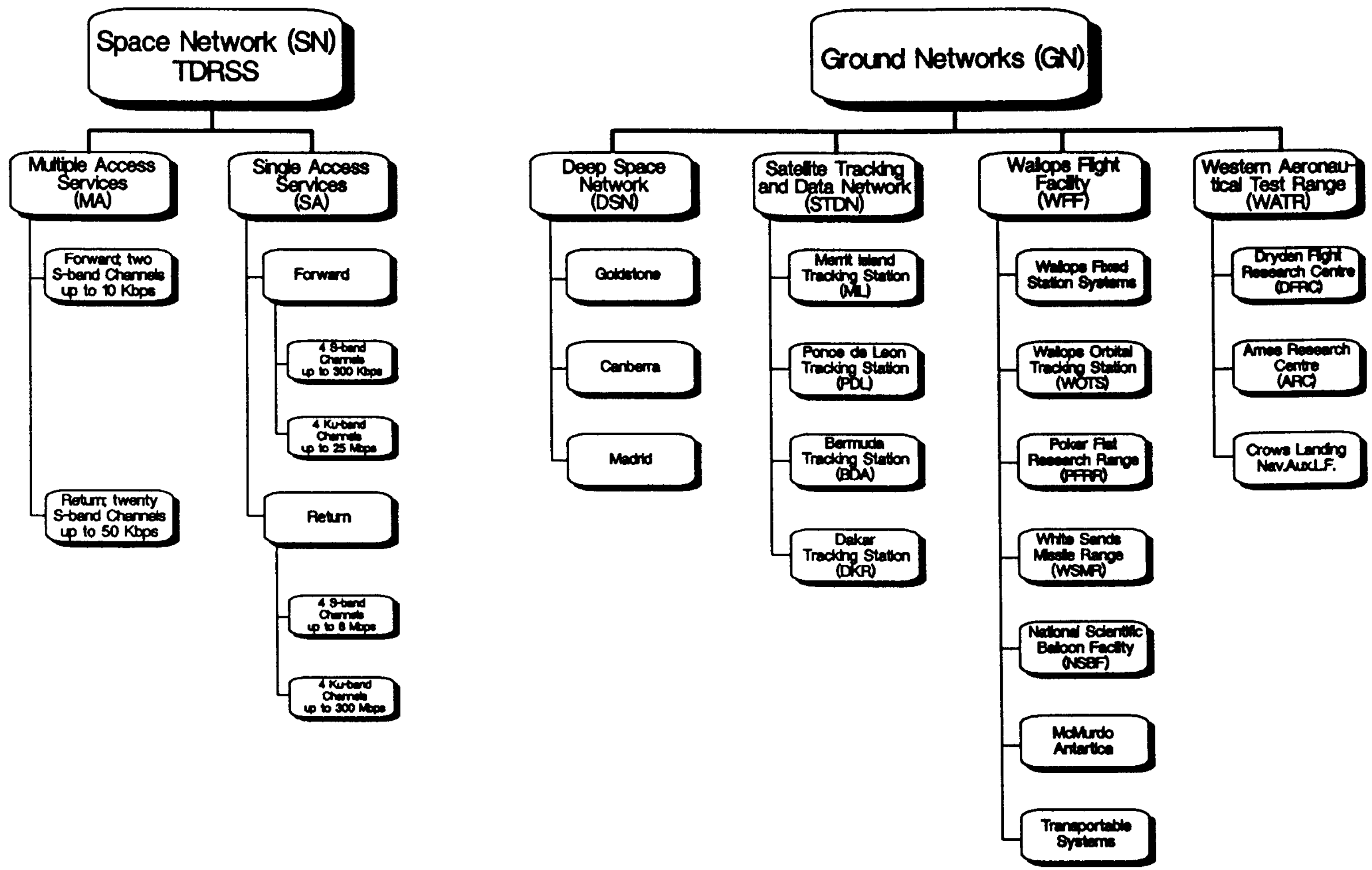

FIGURE 4.2: HIERARCHY OF NASA SPACE AND GROUND NETWORKS

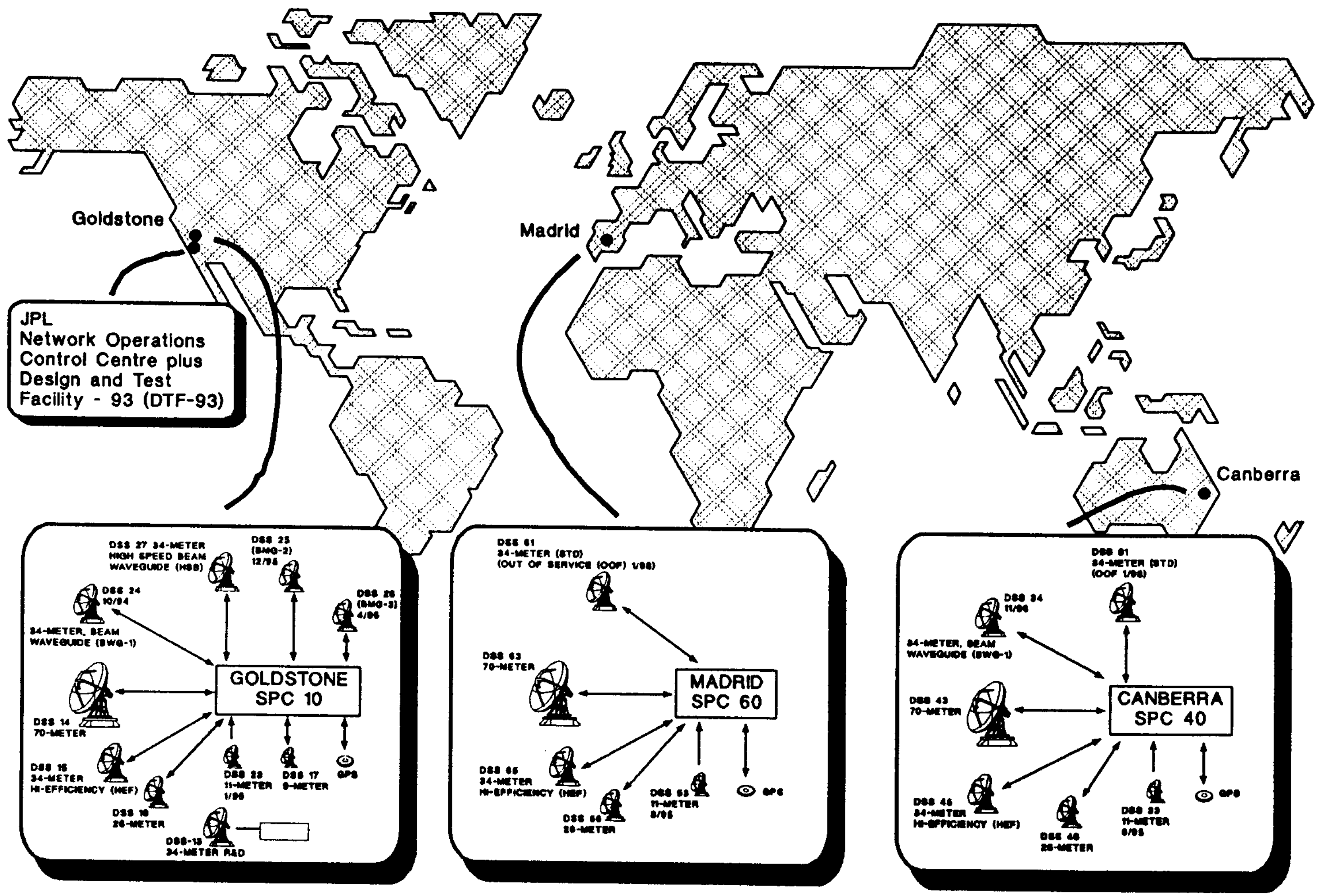

FIGURE 4.3: PLANNED 1997 DSN CONFIGURATION

TABLE 4.8: CHARACTERISTICS OF NASA DEEP SPACE NETWORK 1

	9-m Station (now operational)	34-m High Speed Beam Waveguide Station (operational 3-95)	11-m Subnetwork (operational 11-95)	26-m Subnetwork (now operational)	34-m Standard Subnetwork (will be closed in 10-95, 1-98, 1-98)
Locations	Goldstone	Goldstone	Goldstone, Canberra, Madrid		
Downlink Frequencies (MHz)	2200-2300		8025-8500 14000-15350	2200-2300	2200-2300 8400-8500
Downlink Polarization	RHC/LHC/Linear		RHC/LHC	RHC/LHC or linear	RHC/LHC
Telemetry Modulation	PM(NRZ)/PSK/FM PM(Bi-ϕ)/PSK/FM PM(IRIG)/PSK/FM		X-Band: Carrier only K-Band: QPSK/UQPSK/BPSK (NRZ)	PM(NRZ)/PSK/FM PM(Bi-ϕ)/PSK/FM PM(IRIG)/PSK/FM	PCM(NRZ)/PSK/PM PCM(Bi-ϕ)/PSK/PM
Telemetry Decoding Telemetry Processor	SPC 10		Goldstone: SPC 10 Canberra: SPC 40 Madrid: SPC 60		
Uplink Frequency	2025-2120		7145-7235 15250-15350	2025-2120	2025-2120
Uplink Polarization	RHC/LHC				
Telecommand Modulation	PM(NRZ, Bi-ϕ)		Not available	PM(NRZ, Bi-ϕ)	
Telecommand Encoder/ Controller	SPC 10			Goldstone: SPC 10 Canberra: SPC 40 Madrid: SPC 60	
Ranging/Doppler Tracking	Doppler: Coherent & Non-Coherent Ranging: Side Tone Ranging Coherent & Non-Coherent		Doppler: Coherent Ranging: not available	Doppler: Coherent & Non-Coherent Ranging: Square (coh. only) Sine (coh. & non-coh.)	Doppler: Coherent & Non-Coherent Ranging: 2-Way Coherent (square)
Communications Node					
Function/Project	Category A Missions		Category A VLBI Missions	Category A & B Missions	

TABLE 4.9: CHARACTERISTICS OF NASA DEEP SPACE NETWORK 2

	34-m High Efficiency Subnetwork	34-m Beam Waveguide-1 Stations (operational 10-94 & 11-96)	34-m Beam Waveguide-2 Station (operational 6-96)	34-m Beam Waveguide-3 Station (operational 10-96)	70-m Subnetwork (now operational)
Locations	Goldstone, Canberra, Madrid	Goldstone, Canberra	Goldstone		Goldstone, Canberra, Madrid
Downlink Frequencies (MHz)	2270-2300 8400-8440	2270-2300 8400-8500 31800-32300	8400-8500		2200-2300 8400-8500
Downlink Polarization	RHC/LHC				RHC/LHC/Lin
Telemetry Modulation	PCM(NRZ or Bi-ϕ)/PSK or BPSK or QPSK/PM				
Telemetry Decoding / Telemetry Processor	Goldstone: SPC 10 Canberra: SPC 40 Madrid: SPC 60	Goldstone: SPC 10 Canberra: SPC 40		SPC 10	Goldstone: SPC 10 Canberra: SPC 40 Madrid: SPC 60
Uplink Frequency	7145-7190	2025-2120	7145-7190	7145-7190	2090-2094 2110-2120
Uplink Polarization	RHC/LHC				
Telecommand Modulation	PM(NRZ, Bi-ϕ)				
Telecommand Encoder/ Controller	Goldstone: SPC 10 Canberra: SPC 40 Madrid: SPC 60	Goldstone: SPC 10 Canberra: SPC 40		SPC 10	Goldstone: SPC 10 Canberra: SPC 40 Madrid: SPC 60
Ranging/Doppler Tracking	Doppler: Coherent & Non-Coherent Ranging: 2-Way Coherent (Square)				
Communications Node					
Function/Project	Category A (with some limitations) & B Missions			Category B Missions	

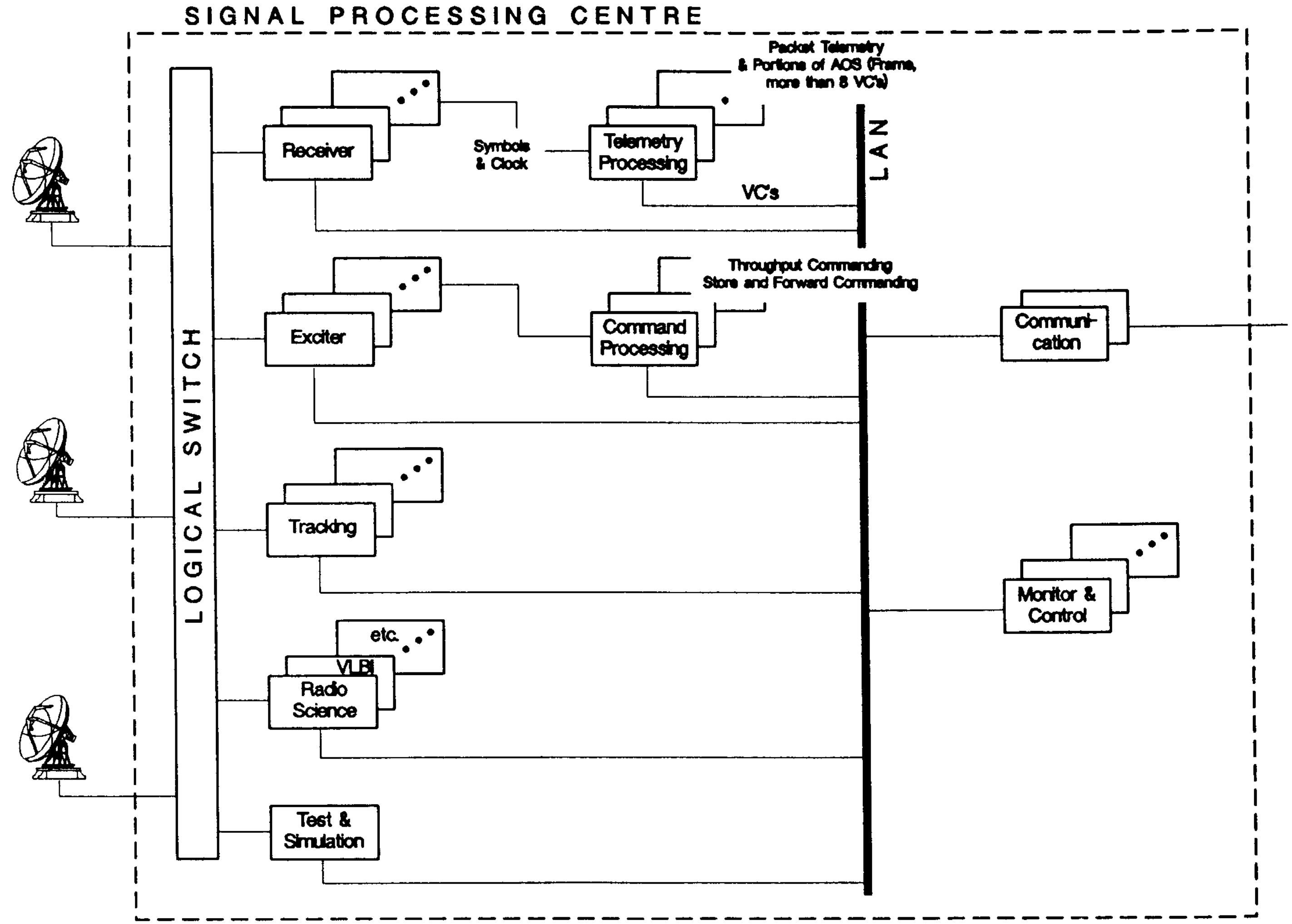

FIGURE 4.4: FUNCTIONS OF JPL SIGNAL PROCESSING CENTRES

TABLE 4.10: NASA GROUND NETWORK (EXCEPT DSN)

The information contained in this table is mostly extracted from Reference [27], pages 2-6 ff and Reference [31].

	Location	Antennas	Telemetry Link Characteristics	Command Link Characteristics	Function	Comments
Satellite Tracking and Data Network (STDN)						
Merrit Island Tracking Station (MIL)	Florida	Two 9m unified S-band	Demodulates, processes and records telemetry in 2200-2300 MHz range; PCM(NRZ-L or biphase)/PM or AM or FM; data rates from 1 b/s to 5 Mb/s. Data are processed by the Information Processing Division (at GSFC). Presently these can be TDM and packetized data. Ref. [27] quotes on page 3-10: "OSC customers should note that TDM data services will not be available for new missions, because this technology is being replaced by frame- and packet-based technology."	From [31]: The 16 kHz subcarrier is the only one authorised for US missions. However, for ESA missions, an 8 kHz subcarrier can also be provided	The STDN provides launch support for Kennedy Space Centre and supports various Space Shuttle and unmanned earth orbiting missions. MIL provides also preflight telemetry and command testing services (also for DSN)	From [31]: Commands generated by the customer and forwarded to GN stations must be structured in a 4800-bit throughput block format to be compatible with onsite systems. The two stations are collocated; MIL controls PDL.
Ponce de León Tracking Station (PDL)	Florida	4.3 m S-band		From [31]: Transmits commands to s/c in the 2025 to 2120 MHz band. The 16 kHz subcarrier is the only one authorised for US missions.		
Bermuda Tracking Station (BDA)	Northwest Bermuda	Two 9m S-band plus C-band radar		From [31]: S-band and UHF (400 to 450 MHz). The 16 kHz subcarrier is the only one authorised for US missions.		
Dakar Tracking Station (DKR)	Senegal	4.3				
Wallops Flight Facility (Fixed Telemetry Systems)						
Meteorological Antenna System (MAS)	Wallops	2.4m	L-, S- and 1680 MHz bands	n/a		
Low Gain Telemetry Acquisition System (LGTAS)	Wallops	2.4m	L-, S- and 1680 MHz bands	FM transmit capability at 30 watts on 547 and 550 MHz		
Medium Gain Telemetry Acquisition System (MGTAS) No 1	Wallops	7.5m	P-, L-, S- and 1680 MHz bands	n/a		

	Location	Antennas	Telemetry Link Characteristics	Command Link Characteristics	Function	Comments
Medium Gain Telemetry Acquisition System (MGTAS) No 2		7.5m				
Wallops Flight Facility (Orbital Tracking Stations)						
NN 1	Wallops	18m receive only	L-, S- and 1680 Mhz bands			
NN 2		9m S-band		Selectable transmit capability of either 200 or 16 watts		X-band receiver in 1996
NN 3		7.3m receive only	1690-1700 MHz	n/a		Dedicated to METEOSAT
NN 4			464-469 MHz			
NN 5		6m command	n/a	S-band; 200 or 16 watts		
Satellite Automatic Tracking Antenna (SATAN) No 1		Array	136-138 MHz	n/a		
Satellite Automatic Tracking Antenna (SATAN) No 2						
SATAN No 3			n/a	147-152 MHz with 10 kilowatts		
Satellite Command Antenna						

	Location	Antennas	Telemetry Link Characteristics	Command Link Characteristics	Function	Comments
Wallops Flight Facility (External and Transportable Stations)						
Transportable Radar, Telemetry and Data Systems		From 2.1 to 6.1 m 8 m as from 1996	P-, L-, S- and/or 1680 MHz bands		Temporary coverage at locations beyond those served by fixed facilities at the Wallops Flight Facility	A transportable station typically consists of a self-supporting instrumentation van paired with an antenna trailer including antenna and pedestal. There are four instrumentation vans, three self-contained telemetry modules, and nine transportable antennas available from Wallops. Antennas range in size from 2.1 to 6.1 meters (6 to 20 feet) in diameter, and cover P-, L-, S-, and/or 1680 MHz bands. By 1996, there will be three fully automated Transportable Orbital Tracking Systems (TOTS) available, each with an 8-meter (26-foot) diameter antenna. The TOTS systems will be S-band and will be upgradable to X-band.
Poker Flat 1	Poker Flat Research Range, Fairbanks Alaska	2.4m	S-, L- and 1680 MHz bands; data are recorded on wideband recorders; could be provided in realtime displays also.		Telemetry data are received from up to six frequencies through the use of a multicoupler	Consists of two tracking dish antennas in a radom, a transmitter van, a tracker van, a computer van and a data van. The normal mode of operations is to use the 2.4m and 4.8m antennas redundantly, but simultaneous tracking of two different targets is possible.
Poker Flat 2		4.8m				
White Sands Missile Range (WSMR) VAB	White Sands	Each station has a 3m autotracking and a 1.2m manual tracking antenna; S-band	n/a			Each antenna feeds 8 to 10 S-band receivers
WSMR N-200			200 watt in tone or frequency shift keying mode			
WSMR Parker			n/a			
WSMR Portable		Two 1.2m	S-band			
WSMR ACSL		?	Realtime data rates up to 200 Kb/s			

	Location	Antennas	Telemetry Link Characteristics	Command Link Characteristics	Function	Comments
National Scientific Balloon Facility (NSBF), Station 1	Transport-able	Two BMS antennas	L- and S-band; LHC/RHC polarization	Command transmitter available	Development, testing, data reduction and single flight service as a launch and downrange site	NSBF is a primary launch facility for the scientific balloon program
NSBF, Station 2		A steerable antenna and a modified 6ft backup antenna			Dedicated to Fort Sumner, NM, for single flight and downrange support	
NSBF, Station 3		Two 6ft BMS antennas			Mobile single flight station for Antarctic and other remote sites	
NSBF, Station 4		A tracking antenna and a 3ft manual antenna			Mobile single flight station to be used primarily in Canada and Australia	
NSBF, Station 5		A steerable antenna and a small manual antenna			Van-based mobiles single flight station to be used in Fort Sumner and California sites	
McMurdo, receive facility	McMurdo, Antartica	10m antenna with auto diversity auto-tracking capability	S- and X-band; RHC/LHC polarization X-band: PCM sampling, NRZ-L differential encoding, QPSK modulation. S-band: (1) PCM sampling, bi-phase encoding, PSK modulation on subcarrier, PM on carrier or (2) PCM sampling, bi-phase-L encoding, PSK (direct) modulation	n/a	Receive and record both RADARSAT X-band downlinks (105 and 85 Mb/s) and the S-band downlink.	A shared facility operated by the National Science Foundation
McMurdo, transmit facilities		0.3m x-band & 0.6m S-band antenna	n/a	X-band & S-band		
Western Aeronautical Test Range						
Dryden Flight Research Centre (DFRC) Dual Band Antenna System		3.6m	L- and S-band for telemetry and television	n/a	Full complement of UHF/VHF/HF communications systems handling, telemetry, video, command, and air-to-air ground voice communications	Three PCM formats generally are used at WATR: NRZ-L, NRZ-M, and Miller coding. The latter is the recommended format.
DFRC, Triplexed Antenna System		6m	L- and S- band for telemetry and L-, S- and C-band for downlinked television	FSK signals in L- and S-band with 50 watts		
DFRC, Multi-frequency Tracking System (MFTS)		Two 3.9m dishes	L- and S-band for telemetry and L-, S- and C-band for television	L- and S-band with 50 watts		
DFRC, Mobile Operations Facility			L- and S-band for telemetry and television	S-band		

	Location	Antennas	Telemetry Link Characteristics	Command Link Characteristics	Function	Comments
Ames Research Centre at Moffet Field (MF), Dual mode autotrack antenna		Combination of small high-gain dish antenna and a low-gain, four element wide beam array	Two L-band receivers	n/a		
MF, Mid-gain antenna system		Small antenna	L-band receiver	n/a	Use for flight telemetry or as the receiver for relayed data from Crows Landing.	
MF, Omni-directional antenna		Low-gain system	L-band receiver	n/a		
Crows Landing Naval Auxiliary Landing Field		Three antenna systems similar to those of Moffet Field	L-band receiver	One of the three can uplink in L-band		

TABLE 4.11: EVALUATION OF THE INTEROP SCENARIOS WITH RESPECT TO THE AGENCY'S INFRASTRUCTURE

NO	NAME	SERVICE REQUIREMENTS CONCERNING SPACE-GROUND LINK	EVALUATION
		(1) MISSIONS SPONSORED BY ESA	
1	ARIANE 5	OS (b): (1) Transmission of ESA platform TLM to NASA ground network (Bermuda station) (2) RNG of ESA s/c	Re (1): See remarks in Section 2.3 Re (2): see under (1)
4	ATV	OS (c): (1) Transmission of ESA platform TLM to Space Station Alpha (2) Transmission of CMD from Space Station Alpha to ESA platform (3) Exchange of RNG data between ESA platform and Space Station Alpha (possibly skin radar ranging)	Re (1): Space Station will follow AOS (see [1]). Thus ATV will be obliged to adapt its system, i.e. essentially using Packet Telemetry with AOS frame. Re (2): Uplink is expected to follow the CCSDS Telecommand Recommendation (with COP 1); this has to be verified. Re (3): Skin tracking should not pose any compatibility problems
5	CLUSTER	OS (b): For ESA platform systems: TLM reception, CMD transmission and RNG through Goldstone and Canberra OS (d): For ESA platform and ESA&NASA payload systems: as for OS (b) OS (f): For a specific NASA high rate data payload: routing of TLM from the instrument to the platform data system and then transmission to Goldstone and Canberra.	Re (b): The spacecraft is using the AOS frame with the semantic of the conventional telemetry. The packets are private, i.e. there are privately defined data in the frame. The forward link uses old systems: data structures and services are not CCSDS compatible. Network Data Interface Units (NDIUs) have been installed in the relevant DSN stations. They have the functions of an ESA station back-end, i.e. input is bits and output is X25 communication frames. DSN could have managed the frames but is not compatible with the ESA ground communication interface. Re (d): NASA payload is routed through the ESA platform, therefore situation as for (b). Re (f): As for (b) General remark: CLUSTER is a typical bad example where the requirements are those assumed for CCSDS work, most CCSDS products were available in time but the project has installed a mission specific solution nevertheless.
6	COBRAS/ SAMBA	OS (b): As OS(b) for ROSETTA	See ROSETTA
7	COLUMBUS PROGRAMME	OS (a), (b) and (c): (1) Transmission of ESA platform (APM) and payload TLM to Space Station Alpha platform data handling system (2) CMD transmission from Space Station Alpha platform data handling system to ESA platform (APM) and payload (3) Voice communication between ESA platform (APM) and Space Station Alpha platform data handling system	Re (1): Application of mission specific protocols and services for which CCSDS has not created any recommendations yet Re (2): Same remark as for (1) Re (3): Same remark as for (1) See also remarks in Section 2.4.
8	CTV (will not be considered any more, because the project has been cancelled during the course of this study)	OS (c): (1) Transmission of ESA platform TLM to Space Station Alpha (2) Transmission of TLM from Space Station Alpha to ESA platform (3) Exchange of RNG data between ESA platform and Space Station Alpha (possibly skin radar ranging) (4) Exchange of voice information between ESA platform and Space Station Alpha	Re (1) through (3): As for ATV Re (4): It is possible that [24] would be applied. During the recent Manned Spaceflight Programme redefinitions this mission has been cancelled for the time being.

NO	NAME	SERVICE REQUIREMENTS CONCERNING SPACE-GROUND LINK	EVALUATION
10	ENVISAT	OS (a): (1) Transmission of ESA platform TLM to NASA stations (Wallops, Poker Flat) (2) CMD transmission from NASA stations (Wallops, Poker Flat) to ESA platform ? (3) RNG of ESA s/c from NASA stations (Wallops, Poker Flat) OS (e): (4) Transmission of ESA payload data to NASA or NOAA stations (e.g. Fairbanks)	Re (1): S-band housekeeping systems will produce TDM telemetry. The interface with the NASA ground stations will be via NDIUs (as for Cluster) (info Palle Soerensen, ESOC) Re (2): Is using the old ESA PCM telecommand system; interface via NDIUs. (info Palle Soerensen, ESOC) Re (3): It is not clear whether ranging will be required from these NASA stations; if yes, compatible ranging systems of the type quoted under footnote 9 are assumed. Re (4): Payload data (both realtime and playback) will be transmitted via X-band direct to the ground and Ka-band via DRS. These data will be CCSDS formatted using the AOS VCDUs. This interface should pose no problems as concerns NASA stations, because they will be modified according to CCSDS Recommendations; the situation is different for NOAA stations as NOAA does not intend to use CCSDS for their spacecraft; consequently also the stations will not be modified, mission specific solutions will be required.
11	ERS 1/2	OS (a): (1) Transmission of ESA platform TLM to NASA stations (Wallops, Poker Flat) (2) CMD transmission from NASA stations (Wallops, Poker Flat) to ESA platform (3) RNG of ESA s/c from NASA stations (Wallops, Poker Flat) OS (e): (4) Transmission of ESA payload data to NASA or NOAA stations (e.g. Fairbanks)	The platform of both spacecraft is derived from the SPOT platform, which has an old telemetry system (modified PCM time division multiplexing); thus the harmonisation of the interfaces between the spacecraft and the NASA/NOAA stations has to be provided through mission specific solutions. This holds true for both, the housekeeping link through S-band and the payload link through X-band.
12	EURECA MISSIONS	OS (a): - Transmission of ESA platform TLM to Shuttle data handling system (via the Payload Interrogator link) - CMD transmission from Shuttle data handling system to ESA platform (via the Payload Interrogator Link)	See remarks in Section 2.5
14	HUBBLE	Ongoing mission, therefore not considered for the time being. Later on a description of the ESA-NASA interfaces may be added for comparison reasons.	
15	HUYGENS	OS (a) (1) Transmission of Huygens platform and payload TLM to Cassini and to DSN (2) Transmission of Huygens CMD from DSN stations to Cassini and to Huygens platform and payload	For reasons of power consumption HUYGENS will not transmit any telemetry (and not receive any telecommand) directly to (from) the ground. It will always communication via the CASSINI information handling system. This concept is also applied during the descent phase, when HUYGENS telemetry is received and stored by CASSINI until it is transmitted to DSN according to schedule. Re (1) and (2): this concerns again the interface between the payload (HUYGENS) and the platform (CASSINI). A mission specific solution will be implemented. CCSDS has not worked out recommendations in this field (see also Section 2.6)
16	INTEGRAL	OS (b): (1) Transmission of ESA platform and payload TLM to DSN stations (probably Goldstone and Canberra) (2) CMD transmission from DSN stations to ESA platform and payload (3) RNG of ESA s/c from DSN stations.	Re (1) and (2): DSN stations and their Signal Processing Centres will become CCSDS compatible within the next years (see [3], page 41 and others); it is expected that INTEGRAL will use the compatible ESA standards (see [32] through [35]). All these ESA standards are CCSDS compatible; thus interoperability should be available. Re (3): The ESA Multi Purpose Ranging System is compatible with DSN.
17	INTER-MARSNET	OS (a) and (b): As OS(b) for ROSETTA	See ROSETTA
18	ISO	OS (b): As OS(b) for ROSETTA (Goldstone support only)	See ROSETTA
20	METEOSAT SECOND GENERATION	OS (c): (1) Transmission of ESA/EUMETSAT platform and payload TLM to NOAA stations (2) CMD transmission from NOAA stations to ESA/EUMETSAT platform and payload (3) RNG of ESA/EUMETSAT s/c from NOAA stations	The MSG Project Manager, Mr. Dieterle, confirmed that MSG will be compatible with current ESA standards on both the S-band and the L-band link. This is compatible with the EUMETSAT policy (info R. Wolf) that all new s/c follow CCSDS/ESA telemetry and telecommand standards. On the other side it is still open what NOAA will do. The NOAA-K,-P,-Q satellites - this is the present situation - will not use CCSDS (info D. Wilson, GSFC). It becomes also more and more likely that Landsat-7 may not use CCSDS (enquiry still running). On this background and because NOAA-O,-P,-Q are intended to be used in cooperation with the EUMETSAT Polar System (EPS) satellites the design of the MSG data handling system may again come under scrutiny.

NO	NAME	SERVICE REQUIREMENTS CONCERNING SPACE-GROUND LINK	EVALUATION
21	METEOSAT	OS (c): (1) Transmission of ESA platform and payload TLM to NOAA ground station (2) CMD transmission from NOAA ground station to ESA platform and payload (3) RNG of ESA s/c from NOAA station.	NOAA has purchased and installed ESA ground stations which are compatible with the METEOSAT system; this system originates from the early 70th and thus has nothing to do with CCSDS.
22	METOP	OS (a): As OS (a) for ERS 1/2 OS (e): As OS (e) for ERS 1/2 OS (f): Communication of NOAA payload with ESA/EUMETSAT platform	Re (a): The satellite system is being developed under the responsibility of ESA for EUMETSAT as the EUMETSAT Polar System (EPS). It will be operated in cooperation with NOAA-O,-P,Q (EPS will provide three morning satellites and NOAA three afternoon satellites). Information from the ESA project (Mr.Lokas from the METOP project group) confirms that the satellite will follow ESA standards both on the S-band and the X-band links. The relevant NASA stations for the S-band link (Wallops, Poker Flat) will be equipped with CCSDS compatible facilities. Re (e): It is not clear what will be the status of the X-band receiving NOAA stations because the corresponding NOAA satellites will not be CCSDS compatible (Info D.Wilson, GSFC). The ESA project data systems Engineer (Mr. Lokas) said, that discussions with NOAA are going on. METOP is at the beginning of Phase B, so changes are still possible. Even that the project reverts its position and uses non-CCSDS solutions in order to be compatible with NOAA-O,-P,-Q. A hilarious situation ! In this situation it was also not clear yet, whether they would be using conventional frames or AOS VCDUs. Probably the latter, at least on the payload link. Re (f): CCSDS recommendations do not exist. There will be a project specific solution.
23	MORO	OS (a) and (b): As OS(b) for ROSETTA	See ROSETTA
24	ROSETTA	OS (b): (1) Transmission of ESA platform and ESA&NASA payload TLM to DSN stations (probably Goldstone and Canberra) (2) CMD transmission from DSN stations to ESA platform and ESA&NASA payload (3) RNG of ESA s/c from DSN stations.	Re (1) and (2): DSN stations and their Signal Processing Centres will become CCSDS compatible within the next years (see [3], page 41 and others); it is expected that ROSETTA will adapt the compatible ESA standards which are all CCSDS compatible; thus compatibility will exist. Re (3): The ESA Multi Purpose Ranging System transponder is compatible with DSN.
27	SOHO	OS (a): (1) Transmission of ESA platform and ESA&NASA payload TLM to DSN 26 m stations (2) CMD transmission from DSN 26 m stations to ESA platform and ESA&NASA payload (3) RNG of ESA s/c from DSN stations. OS (b): (4) Communication of NASA payload with ESA platform data handling system	Re (1) and (2): all SOHO data will be processed by PACOR II at GSFC, which is CCSDS compatible. Re (3): the ESA Multi Purpose Ranging System is compatible with DSN. Re (4): CCSDS did not develop a relevant protocol recommendation (see remarks in Section 2.6); a mission specific solution has been implemented.
28	SPACELAB MISSIONS	OS (a) and (b): (1) Transmission of ESA platform and payload TLM to Shuttle data handling system (2) CMD transmission from Shuttle data handling system to ESA platform and payload	Will not be considered further because of "historical facts".
30	STEP	OS (a): (1) Transmission of ESA platform and ESA&NASA payload TLM to DSN stations (probably Goldstone and Canberra) (2) CMD transmission from DSN stations to ESA platform and ESA&NASA payload (3) RNG of ESA s/c from DSN stations. OS (b): (4) Communication of NASA payload with ESA platform data handling system	Re (1), (2), (3): as for ROSETTA. Re (4): See remarks under SOHO; surely the ESA Packet Utilisation Standard will be applied.
31	ULYSSES	Ongoing mission, therefore not considered for the time being. Later on a description of the ESA-NASA interfaces may be added for comparison reasons.	
(2) MISSIONS SPONSORED BY NASA			

NO	NAME	SERVICE REQUIREMENTS CONCERNING SPACE-GROUND LINK	EVALUATION
39	EOS	OS (d): (1) Transmission of NASA payload TLM to the ESA ground network (Kiruna, Maspalomas, Fucino and others) OS (e) and (g): (2) Transmission of ESA payload TLM to NASA platform data handling system OS (f): (3) Transmission of ESA CMD from NASA platform data handling system to ESA payload	Re (1): This mission will follow CCSDS Recommendations (see [1], page 20), probably using AOS frames; thus, in principle no major incompatibilities should exist with ESA and other European stations which may receive payload telemetry, provided these stations are modified according to current ESA standards (see page 18 and following). As these stations are likely to receive also ENVISAT data, they will certainly be upgraded according to CCSDS. Re (2) and (3): Application of mission specific protocols and services for which CCSDS has not created any recommendations yet.
41	FAST	OS (b): (1) Transmission of CMD from NASA platform data handling system to ESA payload OS (c): (2) Transmission of ESA payload TLM to NASA platform data handling system	Re (1) and (2): Application of mission specific protocols and services for which CCSDS has not created any recommendations yet.
47	LANDSAT 7	OS (c): Transmission of NASA payload TLM to ESA ground network (stations such as Kiruna, Maspalomas, Fucino)	In [1], page 61 it is indirectly quoted that Landsat-7 will be CCSDS compatible. However, there is an oral information from Warner Miller, GSFC: he told the study author that an originally planned new instrument (the High Resolution Multispectral Stereo Imager (HRMSI)) has been given up and thus only the Enhanced Thematic Mapper will remain. In this case there would be no reason to change the onboard data handling system and therefore LANDSAT-7 will not become CCSDS compatible. This has to be confirmed.
52	NOAA-K,-L,-M	OS (b): As for Landsat OS (c)	The NOAA spacecraft will not be CCSDS compatible; they will continue to use a TDM system. See also remarks line 24
53	NOAA-O,-P,-Q	OS (b): As for Landsat OS (c)	The NOAA spacecraft will not be CCSDS compatible; they will continue to use a TDM system. See also remarks line 24
57	SPACE STATION	OS (c): - Transmission of ESA payload TLM to US Laboratory data handling system - CMD transmission from US Laboratory data handling system to ESA payload.	See evaluation under COLUMBUS Programme
58	SPACELAB	OS (c): - Transmission of ESA payload TLM to Spacelab data handling system - CMD transmission from Spacelab data handling system to ESA payload	Will not be considered further, because of "historical facts".

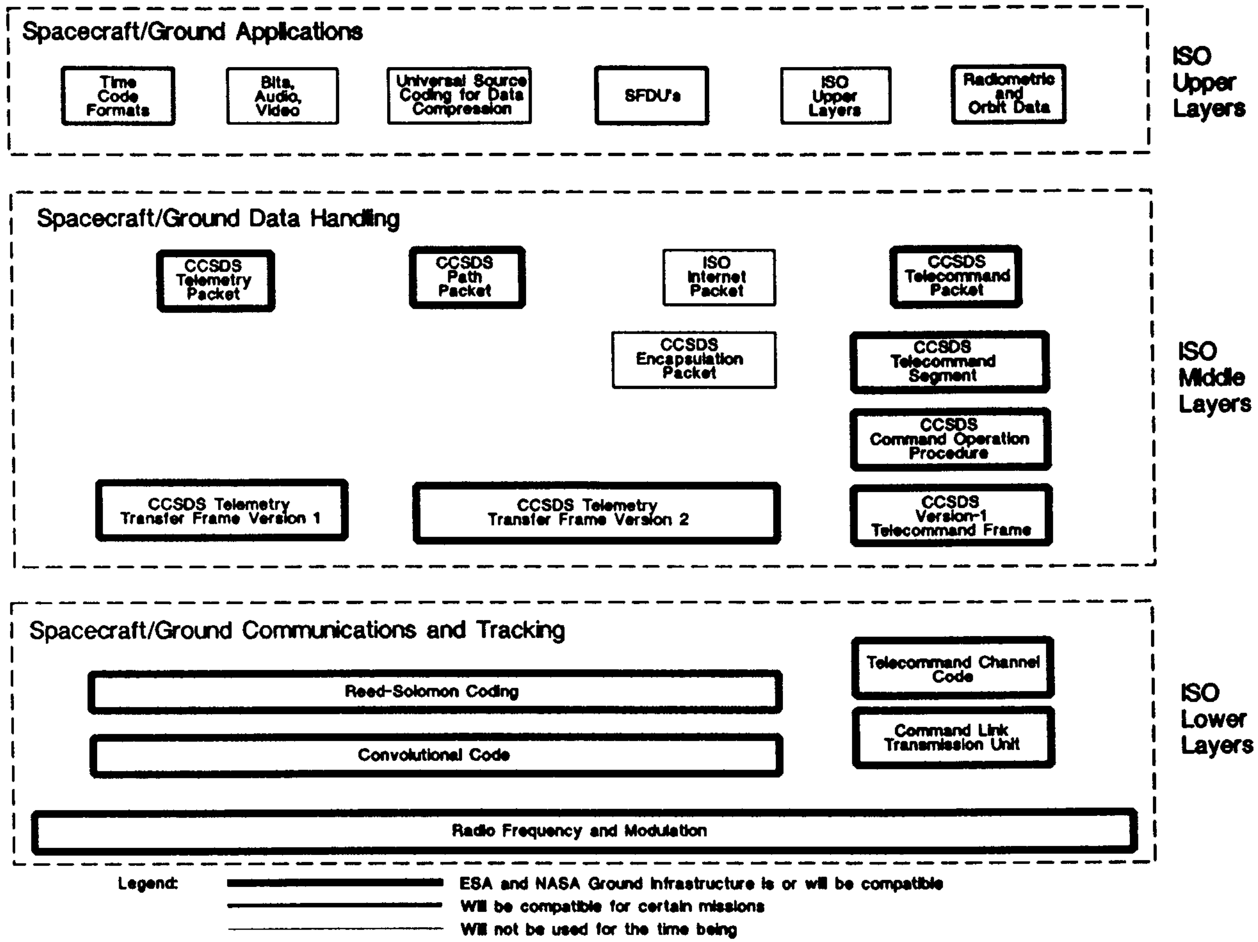

FIGURE 5.1: OVERVIEW OF ESA/NASA COMPATIBLE SYSTEMS

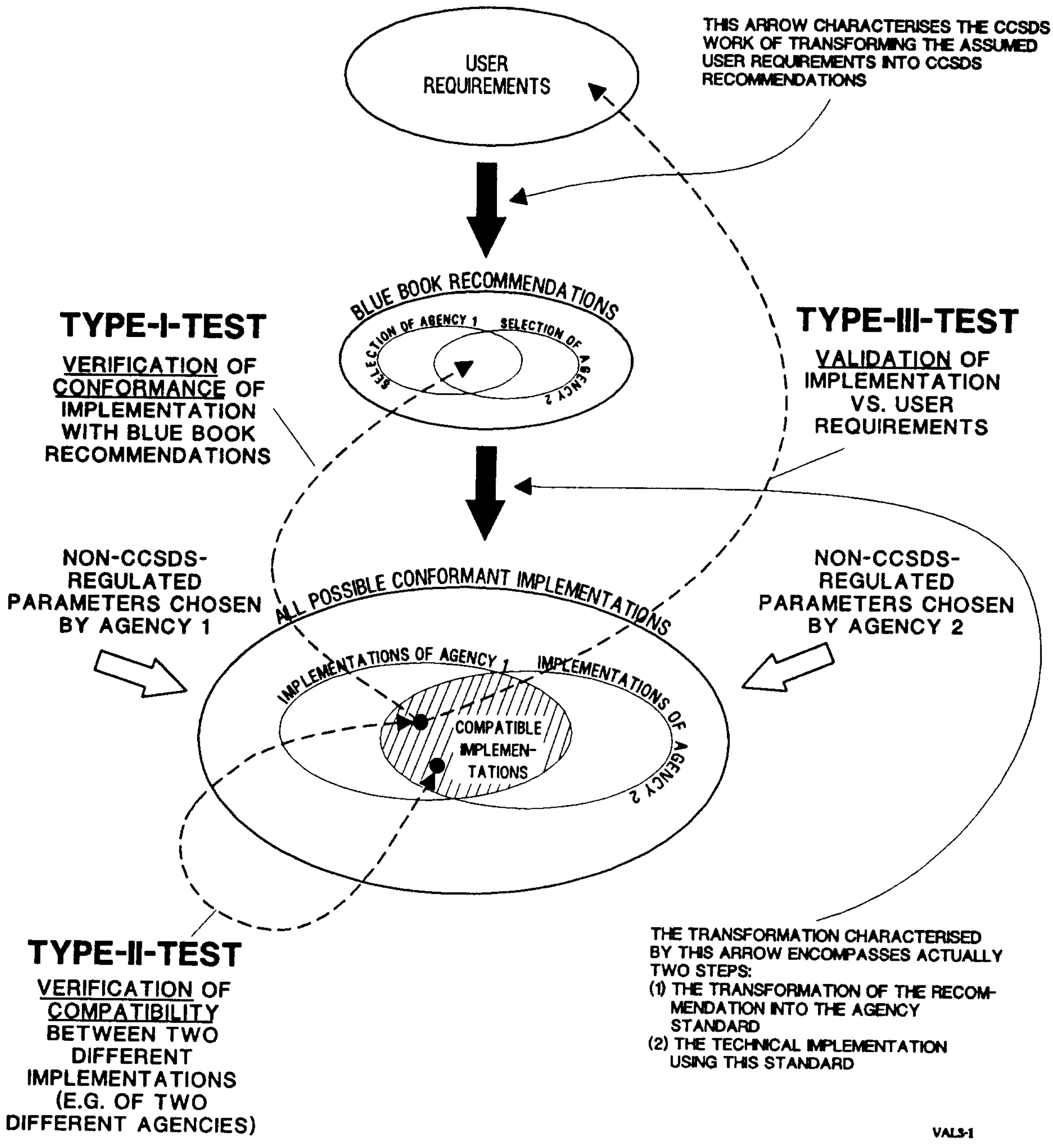

FIGURE 6.1: TEST METHODS OF PRODUCTS DERIVED FROM CCSDS RECOMMENDATIONS