MINUTES OF THE INTEROPERABILITY PLENARY MEETING

TABLE OF CONTENTS

MINUTES OF THE INTEROPERABILITY PLENARY MEETING

EXECUTIVE SUMMARY

The Interoperability Plenary Meeting was held at ESA Headquarters on 21-22 June 1999. During the 1 1/2 day meeting, representatives from seven international space agencies met to discuss and agree on the need for increased interoperability and the method for its implementation. Prior to the Plenary meeting, a survey and individual discussions had determined that the focus should be ground system interoperability.

The Agenda provided an opportunity for each agency to report:

- Past interoperability mission experience – both positive and negative.
- The need for interoperability in the context of that agency's future missions.
- The specific assets of the agency to be made interoperable.
- Current status and plans to implement interoperable standards.

Early in these summary presentations, it became apparent that this group's common goal was to establish ground system interoperability with other agencies at the earliest feasible time. The remainder of the time was spent in determining how best to achieve that goal. Several presentations, and the ensuing discussions, yielded sets of findings. These are repeated below in summary form and represent the results of the Interoperability Plenary Meeting.

Summary of Agencies' Status and Plans Presentations

There were certain recurring themes in the seven agency presentations. The following list summarizes the items most frequently repeated.

1. All agencies have had broad, successful experience with interoperability in the past.
2. Collaborative missions will increase and become more important.
3. Agencies expect that interoperability will be more necessary in the future.
4. CCSDS in-place standards completely cover the space link and are widely used.
5. Past ground interfaces have been customized and have little commonality.
6. One advantage of a single, uniform interface will be to facilitate integration and testing.
7. Most agencies concur the SLE interface provides the needed ground system interoperability.
8. A preponderance of the agencies intend to implement the SLE interface in some form.
9. Several SLE Service Definitions for ground-to-ground transfer are now available.
10. Return All Frames (RAF), Return Virtual Channel Frames (RCF), Command Link Transmission Unit (CLTU), and Forward Space Packet (FSP) should be the first SLE Services implemented by agencies.
11. Funding limits and mission needs determine the extent and location of SLE implementation.
12. SLE will be used for support of the Integral, Rosetta, and Mars Express missions.

Summary of Discussions Following Future Collaborative Missions Presentations

This session was intended to promote discussions among persons attending the Interoperability Plenary about future collaborative missions and their needs. The following summarizes the points made by the various representatives.

EXECUTIVE SUMMARY (Continued)

1. CCSDS space link standards are utilized by most agencies facilitating interoperability.
2. Within the Space Science community, the SLE interface is generally accepted.
3. One advantage of a single, uniform interface will be to facilitate integration and testing.
4. The CCSDS is the appropriate organization to develop data-handling standards for the international space agencies.
5. Concern was expressed that the Earth Science community and CCSDS have not investigated the application of CCSDS standards to Earth Science missions in order to achieve greater interoperability. A closer tie between these groups was encouraged.
6. Concern was also expressed that the clock-data interface currently baselined for EOS does not facilitate data accountability throughout the data transfer process.
7. There was a consensus that CCSDS should work with CEOS to adopt the SLE interface and to assist the Earth Sciences community in the SLE's development and implementation.

Summary of Discussions Following Architecture for Interoperability Presentation

Ground system interface architecture is important because it must be applicable to a large number of missions flown by many agencies. This presentation described the Space Link Extension (SLE) interface architecture and its characteristics. The following items summarize important comments made following the presentation.

1. Four basic services should be implemented at the outset; Telecommand (CLTU, FSP) and Telemetry (RAF, RCF).
2. The CCSDS should be encouraged to specify a core set of Management Services needed to facilitate operations of the services in 1 above.
3. Services for the exchange of radio metric data should be the next priority. The CCSDS should be asked to consider both the Spacecraft-Planet Kernel (SPK) and the Orbit Data File (ODF) for the exchange of trajectory and pre-solution radio metric data respectively, to determine whether these can serve as interim or final standards.
4. It is impractical, in most cases, to permit an investigator to have direct access in order to send commands to a spacecraft. Safety checking by a central mission system is required.
5. The Applications Layer is important to interoperability and the SLE interface provides that capability.
6. Within NASA, there is still a discussion about the suitability of IP for the space link. Several concerns were identified: 1) IP is not RF bandwidth efficient, 2) IP will not operate well with long round-trip-times (RTLT), 3) IP is not satisfactory where multiple sessions are needed, but only for single sessions having short RTLTs, and 4) IP may not work well over noisy links.

EXECUTIVE SUMMARY (Continued)

Summary of Discussions Following In-Place Standards Presentation

The CCSDS is in its 18th year. In this time, it has developed a set of internationally and industrially accepted standards covering the Space Link (SL). It is now completing a 2nd generation set of standards for the SL. The CCSDS has also produced a draft set of standard service definitions that form the basis for an interoperable ground system. This presentation described those standards and the comments below were made during the discussions following the presentation.

1. SCPS is Internet-like protocol permitting end-to-end telescience operations, which are time disjoint.
2. Asynchronous Transfer Mode (ATM) operations may be possible but will not efficiently use the space link because of the requirement for continuous connectivity and high overhead.
3. Very few missions require a "joy-stick" operational mode and some agencies would prohibit that sort of operation entirely because it is both risky and expensive.
4. Lack of system performance accountability by ground stations has been a major problem in the past. The SLE interface, and associated services, can remedy this deficiency.
5. Unlike present interfaces, the SLE wraps protocols, which have not been terminated at the ground station, with additional information needed for processing and sends them to a central location. It provides the same capability in the reverse direction for commands.
6. SLE, which is at the Applications layer, can reside on top of any Network protocol including TCP/IP. TCP/IP is baselined by many agencies.
7. Initial SLE services for interagency interoperability should be CLTU, FSP, RAF, and RCF.
8. The CCSDS has begun work on the Management services. When complete, it will permit end-to-end automated operations. After the first set is completed in 6-9 months, they should begin work on Mission Control services.
9. Plenary meeting discussions identified an issue: Is it necessary to implement the SLE *Service Provider* function interface at the stations or is it sufficient to provide it at a central location for each agency?

EXECUTIVE SUMMARY (Continued)

Summary of Development of Agency Positions

At the conclusion of the formal presentations pertaining to ground system interoperability, agency representatives paused to consider what they had heard and to develop a set of findings for their agency based on the discussions. Each agency was asked to retire and consider its position with regard to several key issues. Nicholas Bobrinsky identified the points to be addressed by each agency:

1. Is your agency committed to interoperability?
2. What are the preferred standards that should be applied in interface design?
3. What is your agency's planned methodology for implementation and capabilities?
4. Do you have an interim interface to be used until the general solution is in place?
5. What is your schedule for implementing the recommended interface?
6. What Management services are needed?

Summary of Agency Consensus

Following the recess, individual agencies presented their findings. Using the agency responses, Mr. Bobrinsky prepared a composite summary of the results:

1. All agencies are committed to becoming interoperable.
2. Agencies believe that the CCSDS is the proper forum to decide technical issues. ITCOPs are the correct group for administrative and management issues as well as for coordination.
3. DLR, ISAS, CNES, ESA, and NASA all believe that the SLE interface with RAF, RCF, CLTU and FSP services is the correct one. ASI will conduct a feasibility study. NASDA has no plans for SLE at this time.
4. Implementation schedules will be mission driven. Missions such as Integral, Rosetta, Mars Express, Solar-B, and MUSES-C are drivers. Most agencies will implement the SLE service user function before they will build the SLE service provider function.
5. Interim solutions include principally NDIUs, protocol converters, and an early set of SLE services.
6. Today, Management services consist of a set of bilateral agreements. In the future, a CCSDS standard should be agreed allowing most agencies to implement the required functions in a coherent way.

EXECUTIVE SUMMARY (Continued)

Summary of Wrap-Up Session

Following Mr. Bobrisky's summary of the agency consensus, agency representatives were invited to add their comments for the record. The following are some of the more important remarks made by individuals attending the Interoperability Plenary Meeting. Persons making the comments are identified by name.

1. Agencies should provide guidance to the CCSDS to assist in prioritizing their standards development (R. Miller). The Plenary concluded that Agencies should provide this guidance through the existing Inter-Agency Coordination Group (IACG) Working Group-4 (WG-4) and by various Inter-Agency Tracking, Communications, and Operations Panels (ITCOPs).
2. CCSDS should be encouraged to update standards in other areas such as radio metrics so as to provide SLE service specifications in commonly needed areas (P. Maldari).
3. Agencies need to make sure that the CCSDS resources are used efficiently (CNES).
4. A multilateral Interagency Advisory Group (IAG) for space communications should be formed so that all agencies are represented in a single forum. It should undertake the task of negotiating many of the issues presented at this Interoperability Plenary Meeting (Group). Bilateral groups could continue but there may be a need for an oversight group to provide direction to development groups (R. Spearing).
5. Would the IAG replace the bilateral groups (D. Dale)?
6. Once the IAG is formed, what will be its relationship to other groups such as the IACG (unknown)? The IAG Charter may be the place to specify the relationships with other organizations (R. Spearing).
7. The IAG should not meet on a specific schedule. Rather, their meetings should be tied to events such as a mission need (D. Dale).
8. SLE services development should be driven by mission needs and there should be no deviation from those established for the current implementation. A person responsible for working within the group should not deviate from previously agreed specifications without the prior permission of the multilateral working group (P. Maldari).
9. Someone should be responsible for monitoring the entire process and the multilateral IAG is the right one (R. Spearing).
10. R. Spearing accepted the responsibility for taking the lead in establishing the IAG and will prepare a draft charter.

MINUTES OF THE INTEROPERABILITY PLENARY MEETING

The first Interoperability Plenary meeting convened at 2 p.m. on Monday 21 June 1999 at the Headquarters of the European Space Agency in Paris, France. Representatives from ASI, CNES, DLR, ESA, NASA, and NASDA were present. The following persons attended some or all of the sessions during the following 1 1/2 days.

Carlo de Libero	ASI/Telespazio	James Costrell	NASA
Maurizo di Ruscio	ASI	Charles Holmes	NASA
Mauro Donati	ASI	Adrian Hooke	NASA
Enzo Letico	ASI	Angelita Kelly	NASA
Roland Ivernez	CNES	Philip Liebrecht	NASA
Jean-Marc Soula	CNES	Warren Martin	NASA
Y. Trempat	CNES	Lindolfo Martinez	NASA/CSOC
Peter Piotrowski	DLR	Richard Miller	NASA
Hubertos Wanke	DLR	Anita Renteria	NASA/CSOC
Nicholas Bobrinsky	ESA	Rich Schell	NASA/CSOC
David Dale	ESA	Robert Spearing	NASA
Georges Delmas	ESA	Gael Squibb	NASA
John Ellwood	ESA	Robert Stelmaszek	NASA/GSFC
Paolo Maldari	ESA	Wallace Tai	NASA
Carlo Mazza	ESA	Bill Watson	NASA
Manfred Warhaut	ESA	Mitsuhiko Fuda	NASDA
Keiken Ninomiya	ISAS	Kanichiro Kashiwagi	NASDA
Takahiro Yamada	ISAS	Shizuo Yamamoto	NASDA

1.0 INTRODUCTORY REMARKS

The meeting began at 2:00 p.m. on Monday 21 June 1999. Nicholas Bobrinsky speaking for ESA, the hosting agency, introduced support staff Barbara Brossmann and Maren Lemke. Each of the persons named above introduced themselves and stated their position within their agency.

Jim Costrell (NASA) began the meeting by presenting the draft agenda containing items to be discussed and recommending a procedure for the Plenary to follow. Hearing no objections upon inquiry whether the Agenda was complete, it was adopted without modification. A copy of the Agenda can be found in the Section entitled *Meeting Information.*

During his introductory remarks, Bob Spearing observed that a survey and discussions prior to this meeting established a consensus in three areas. First, interoperability is needed to improve agencies' operational efficiencies. Second, that this Plenary meeting should define both scope and the policies leading to interoperability among agencies. Third, that this Plenary meeting should focus on ground system interoperability.

Each Agency was asked to identify candidate facilities to become interoperable and to agree upon a standard architecture for achieving ground system interoperability. Mr. Spearing noted that the CCSDS Space Link Extension (SLE) interface specification has achieved sufficient maturity to be considered as the primary candidate for the interface architecture.

Plenary representatives were also asked to describe additional work that will be needed by their agency to achieve interoperability. The suggested process for identifying areas of future work would be a series of presentations by each agency reviewing:

- Past interoperability mission experience – both positive and negative.
- Their need for interoperability in the context of that agency's future missions.
- The specific assets of the agency to be made interoperable.
- Current status and plans to implement interoperable standards.

Mr. Spearing observed that the Plenary should consider future collaborative missions requiring interoperability in order to identify both the architecture and the capabilities needed to provide ground system interoperability for these future missions. He recommended that the Plenary pause following these presentations to agree upon a preliminary set of findings before proceeding to discussions of future interoperability needs beyond the ground system. These findings will help to focus on the specific actions, commitments and steps needed to achieve interoperability.

Mr. Spearing's presentation can be found in the Section entitled: *Introduction.*

2.0 25-MINUTE AGENCY PRESENTATIONS

Each presentation was designed to cover the four specific areas listed above. Here, the objective was to learn if each agency's experiences pointed to a common set of conclusions.

2.1 ESA's Status and Plans – Nicholas Bobrinsky

Two interface types have been used by ESA in the past: Network Data Interface Units (NDIUs) and Protocol Converters. NDIUs are comparatively large and expensive devices making Protocol Converters attractive because of their smaller size and lower cost. However, protocols tend to be agency dependent with the result that protocol converters must be modified when ESA interfaces with different agencies.

Starting with Integral, ESA is implementing the *service user* function of the SLE interface. It will be used for future missions such as Rosetta and Mars Express. While expensive, the SLE interface is easily reusable on future missions. Initially, the following services are envisioned:

- Return All Frames (RAF)
- Return Channel Frames (RCF)
- Operational Control Field (OCF)
- Command Link Transmission Unit (CLTU)
- Forward Space Packet (FSP)

ESA noted that SLE implementation is expected to cost "several MEuros" and so will only be implemented at the ESOC Control Center at Darmstadt and not at the ESA ground stations. Moreover, the initial implementation will not permit ESA to be a service provider, only a service user. Mr. Bobrinsky noted that before ESA expends additional sums needed for full, bi-directional SLE interoperability at its ground stations, the following conditions must be met:

- Integral, Rosetta, and Mars Express must successfully demonstrate ESA Control Center - NASA ground station operation using the SLE interface.
- ESA must have specific requests from other agencies to access services from ESA ground stations.
- A solid set of CCSDS Blue Books is available.

ESA has currently baselined the CCSDS Service Recommendation Issue-2 Red Books in their design of the SLE interface for Integral and Rosetta. Any variations between these documents and the final CCSDS Blue Books will have to be addressed after the Integral implementation is complete. Management services are based on an ESA/NASA-JPL agreement for Integral. ESA's SLE development specifies a reusable Application Programming Interface (API) library. Rich Miller inquired whether agencies could reduce SLE interface costs by each implementing a subset of APIs and then sharing them with other agencies.

ESA's Mission Control Center facilities to be made interoperable include those for Integral, Rosetta, Mars Express, and Envisat missions. Ground stations interoperability will be provided at the Kourou and Perth 15M, Perth 35M Redu, Vilspa I, Vilspa II, TS1, Kiruna, Malindi, and Maspalomas stations.

Mr. Bobrinsky's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.2 NASA's Status and Plans – Gael Squibb

Mr. Squibb reported that NASA has inter-operated with CNES, ESA, DLR, ISAS, and NASDA. Typically, each of these interfaces has been customized to the specific agency resulting in high maintenance and operations costs. He noted that the time has arrived to specify a standard interface between all agencies.

Past interface problems included:

- Inflexibility of the NASCOM protocol.
- Incompatibility between X.25 and TCP/IP.
- Need to negotiate, document, implement, and test bit-level interfaces for each mission.
- An inflexibility of the manual scheduling requesting system.
- The need to place mission unique equipment at ground stations increasing operational complexity and costs.

NASA facilities to be made interoperable with other agencies include those of the Deep Space Network (DSN), the Ground Network (GN) and the Space Network (SN), including their several control centers. Time will be required to achieve this interoperability but the strategy must include an orderly development through the use of standards. New standards may be required and agencies must negotiate a process for evolving from their present standards to the new ones.

Mr. Squibb observed that the CCSDS has been, and will continue to be, a cost-effective choice for most space missions. Most CCSDS standards have also been adopted as ISO standards. As a result, there is a large Commercial-Off-The-Shelf (COTS) investment in current CCSDS standards.

NASA is committed to interoperability of the DSN, GN, and SN with international space agencies. SLE will be the standard DSN interface with all space agencies for all CCSDS compatible missions. When the need for interoperability with the GN and SN arises, SLE will be a candidate along with the then current ensemble of standards. The most cost-effective solution will be selected.

Since it is unclear when inter-agency interfaces with the GN and SN will be needed, it would be premature to specify a particular design at this time. Meanwhile, commercial equipment providers will be encouraged to adopt SLE interfaces to widen their customer base. NASA's incremental approach to interoperability permits the infusion of new technology.

CSOC's *Integrated Operations Architecture* (IOA) will be implemented to meet NASA's international commitments. The IOA will continue to support CCSDS space-to-ground protocols and the SLE interface is consistent with the IOA's evolution towards a layer 3 protocol for all ground-to-ground communications. With particularity, the IOA will support the SLE interface for Integral to 1) validate the SLE transfer protocol and 2) to take a first step in reducing interoperability costs through the use and re-use of COTS.

A Management Services layer should be specified, but the time scale for its development and implementation can only be determined in consultation with participating agencies.

Mr. Squibb's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.3 ASI's Status and Plans - Mauro Donati

In the past, the Malindi S-band (2 GHz) station has been used with both ESA and NASA facilities. It provides very good coverage in Africa. Past missions requiring interoperability included SIRO, LAGEOS, ITALSAT F1, F2, and SAX.

Apart from past programs, ASI foresees the need for interoperability with several future missions including MITA, PRIMA, and SKYMED/COSMO. Generally, interoperability will be needed during the LEOP, LEO, MEO, and GEO mission phases.

ASI identified several facilities to become interoperable. Malindi, Fucino, Sardinia, and Mare-SS Earth stations are all candidates for interoperability. In addition, ASI provided a substantial amount of technical information about the stations including geographical location, link parameters and diagrams, and types of missions supported.

Mr. Donati observed that "ASI is aware that it is most important to implement interoperability". He was unsure whether Malindi complies with all relevant CCSDS Recommended standards. ASI will study the problem, with its supporting industry, and develop plans and schedules for making the Malindi station interoperable, to request Telespazio to make some of its Fucino facilities interoperable, and to study and implement the Sardinia antenna to be fully interoperable using CCSDS compliant protocols.

Mr. Donati's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.4 CNES's Status and Plans - Jean-Marc Soula

Mr. Soula began by noting that CNES has emergency cross-support agreements in place between four CNES Earth stations and NASA, NASDA, and the Swedish Space Corporation's Kiruna, Sweden station. He presented a diagram showing the CNES Network Operations Center's interfaces with S-band stations in Kourou, Assaguel, Hartebeesthoek, Kerguelen, Kiruna NASA and NASDA. In addition, there are interfaces to the Telsat Ku-band and the Intelsat C-band networks. His presentation listed some 50 missions that have required interoperability in the past. NDIUs, different from those of ESA, have been used for interfacing with some agencies.

CNES stations primarily support TT&C. NASCOM blocks have been the usual method of data exchange although X.25 and IP have been used with a protocol converter when interfacing with ESA. A CNES protocol known as HDLC has also been used with some agencies.

With regard to future plans for interoperability, Mr. Soula stated that there are two approaches. First, if the decision is made to implement the SLE interface, then CNES will use it and encourage its adoption for ATV. Second, they foresee interoperability at a simple level, which would be sufficient for launch and routine mission support. Mr. Soula's presentation lists 9 S-band missions and 8 other missions that are likely to require interoperability in the future.

CNES does not see a short-term SLE requirement during 1999 and 2000 but believes that it will be possible to implement SLE services in the 2002-2003 time period as part of a planned upgrade. In the longer term, "CNES fully supports actions intended to improve interoperability". Mr. Soula noted CNES's contribution to CCSDS Panel 3 and stated support for the SLE RAF and CLTU services. Complexity and costs will determine the CNES path to interoperability.

Mr. Soula's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.5 DLR's Status and Plans - Peter Piotrowski

DLR has had substantial past interoperability experience with some 15 scientific missions, 15 communications satellites, and 9 manned missions. DLR's German Space Operations Center (GSOC) has successfully cooperated with CNES, ESA, INPE, ISRO, KARI, NASA, NSPO, and ZUP. Typically, DLR's 9-, 15-, and 30-meter stations operating at S-band and their 11-meter station at Ku-band have been used for support. DLR's GSOC is often used as a nodal point.

GSOC is planning an improvement program, which should be completed by June 2001. It is intended to both modernize and automate systems at the Weilheim stations and in DLR's control center at Oberpfaffenhofen. During this modernization campaign, systems will be made compliant with up-to-date CCSDS standards, including SLE. Virtually all systems will need to be replaced and DLR will do so using as much Commercial-Off-The-Shelf (COTS) equipment as possible. A state-of-the-art monitor and control system is planned.

Mr. Piotrowski proposed a common, cooperative S-band ground station network to increase the availability to CNES, DLR, ESA, NASA, and other agencies wishing to participate. To further this objective, DLR intends to increase its cooperation with all national European space centers.

Mr. Piotrowski's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.6 NASDA's Status and Plans - Kanichiro Kashiwagi

NASDA has also had a considerable amount of past interoperability experience, mostly with NASA. NASDA named 32 different missions that required interoperability in the years 1975-1997. Past support to NASDA has involved both ground stations and data relay satellites.

Mr. Kashiwagi summarized NASDA's activities within the Space Network Interoperability Panel (SNIP) by describing several compatibility tests between Japanese spacecraft and TDRS and between NASA missions and COMETS SN.

Future cross support is important, particularly in emergencies. In addition, several future missions were identified which will require future interoperability. NASDA is planning to utilize the ARTEMIS data relay satellite under an existing Memorandum of Understanding (MOU) between NASDA and ESA.

Mr. Kashiwagi described NASDA's plans to replace the present ground network because of its age. Goals of this plan include an ability to handle different types of satellites, a global presence of NASDA ground stations, and a significant reduction in operations costs. A series of 10-meter stations will be located at Katsuura, Masuda, and Okinawa and portable stations will be placed in foreign countries such as Kiruna, Sweden; Santiago, Chile; Maspalomas, Spain; and Perth, Australia. New stations will be CCSDS compliant. TCP/IP is baselined but the SLE interface will be implemented in these stations *as needed.*

All stations, both domestic and foreign, will be remotely operated and monitored from NASDA's Control Center at the Tsukuba Space Center. This real-time operational link is desirable to permit rapid planning and execution in the event of a spacecraft or station failure. Tsukuba will also have a compatibility test facility to verify the proper operation between spacecraft and NASDA's ground network. Construction of the all ground stations and the Tsukuba control center is expected to be complete in March 2002.

Mr. Kashiwagi's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.7 ISAS's Status and Plans - Takahiro Yamada

ISAS has also had broad experience operating with the DSN and the University of Chile, particularly within the past ten years. During that period, ISAS experienced no major difficulties. However, Mr. Yamada tendered some suggestions to facilitate interoperability.

For example, it would simplify support requests if they could be handled using electronic data management methods (e.g., the SLE Services Management). Second, NASCOM blocks should be replaced with a modern communications protocol (e.g., CCSDS SLE Services).

With regard to the need for future interoperability, ISAS foresees the need for international interoperability for several missions in the time period 2000 to 2005. With particularity, cross-support will be needed:

- For mission critical operations.
- To increase the amount of returned science data.

ISAS facilities to be interoperable include the:

1. Kagoshima Space Center (20M and 34M antennas and control center).
2. Usuda deep space complex (64M antenna).
3. Sagamihara Space Operations Center.

ISAS is currently in the process of designing an SLE Services server for installation at its Sagamihara Control Center. It will be available in the Spring of 2000 and will be used for the support of the MUSES-C mission. Initially, the server will be implemented to provide only a *Services User* function; however, the *Service Provider* capability will be added as soon as there is an agreement with another agency for ISAS to support their mission.

To facilitate interoperability, ISAS recommends that all missions should:

1. Use the CCSDS Path and Data Link protocols on the space link.
2. Use the same protocol in ground system computers sending/receiving data.
3. Mission specific information should be managed by a single database.

In addition, ISAS would like to see emphasis placed on development of the CCSDS Management Services Recommendation. However, ISAS believes that it should be implemented using a file-based system, rather than a network management protocol. This should help to replace documents such as the Mission Requirements Request, Detailed Mission Requirements, and others. Mr. Yamada stated that the SLE Services Management should be fully implemented to permit on-line monitoring and control of the ground facilities.

Mr. Yamada's presentation can be found in the Section entitled: *Agency Status and Plans.*

2.8 Summary of Agencies' Status and Plans Presentations

Certain themes recurred in the seven agency presentations. The following list summarizes the items most frequently repeated.

1. All agencies have had broad experience with interoperability in the past.
2. Collaborative missions will increase and become more important.
3. Agencies expect that interoperability will be evermore necessary in the future.
4. CCSDS in-place standards completely cover the space link and are widely used.
5. Past ground interfaces have frequently been customized and have little commonality.
6. Most agencies concur that the SLE interface provides the needed interoperability.
7. Several SLE Service Definitions for ground-to-ground transfer are now available.
8. RAF, RCF, CLTU, and FSP will be the first SLE Services implemented.
9. SLE will be used for support of the Integral, Rosetta, and Mars Express missions.
10. Most agencies intend to implement the SLE interface in some form.
11. Funding limits and mission needs determine the extent and location of SLE implementation.

3.0 FUTURE COLLABORATIVE SPACE MISSIONS

Agencies were invited to make presentations describing their future plans for collaborative missions in order to stimulate discussions about the characteristics needed for interoperability. Because these are future missions, each presenter noted that their material was preliminary in nature and represented the plans and desires of their respective scientific communities. Each organization's ability to implement and fly these missions is dependent upon the respective agency's funding.

3.1 NASA's Space Science Future Collaborative Missions - Chuck Holmes

Mr. Holmes began by observing that CCSDS standards permit uniform data handling throughout the space link. He provided a diagram showing five separate interfaces beginning with the spacecraft's instruments and ending with the several PI teams. Each of these interfaces was described together with both the current and emerging implementation practices.

Mr. Holmes noted that efficient interoperability requires standard interfaces throughout the agencies' data systems. Simplified integration and testing, resulting in lower mission development costs, will be a significant by-product of uniform interfaces. He pointed out that there has been a trend from packetized envelopes to higher file transfer layers in recent years.

The NASA Space Science presentation concluded with a large list of past and prospective collaborative deep space missions involving most of the Agencies present at the Interoperability Plenary meeting. In each case, the data interfaces, applicable to that mission, were identified.

Mr. Holmes's presentation can be found in the Section entitled: *Future Collaborative Missions.*

3.2 ESA's Space Science Future Collaborative Missions - Manfred Warhaut

ESA's presentation began with definitions of four levels of cross-support. Mr. Warhaut proposed that these definitions be used as a basis for interoperability:

1. Prime Support ~ Station is scheduled and mission actually receives scheduled support.
2. Tracking Support ~ Data is used to complement orbit/trajectory determination.
3. Backup Support ~ After ground station outage, support is provided within 1-2 days of request (backup station is not scheduled and there is no hot backup).
4. Emergency Support ~ After spacecraft emergency is declared, a suitable station is brought on-line within 1-2 hours.

Mr. Warhaut then described three types of ground system interfaces, two of which have been used in the past.

1. Protocol Converters have been used to translate NASCOM 4800-bit blocks to ESA standard or ESA/CNES Pasarelle.

2. Network Data Interface Units (NDIUs or NDIU Lites) have been provided by ESA when interfacing to a foreign station. Typically, they were connected to ESA's Control Center via dedicated X.25 circuits.

3. Space Link Extension (SLE) comprises a standard set of services, defined by CCSDS Panel 3, to provide interoperability between ground stations and control centers.

He observed that, while Protocol Converters and NDIUs remained as interface options in the immediate future, ESA preferred the SLE interface for missions launching in or after 2003 because of its broad applicability.

Mr. Warhaut's presentation concluded with a list of future space science missions and their planned ground interface types together with the specific services needed for their support.

Mr. Warhaut's presentation can be found in the Section entitled: *Future Collaborative Missions.*

3.3 NASA's Earth Science Future Collaborative Missions - Angie Kelly

Earth science missions have a goal of expanding scientific knowledge of the Earth's system by integrating knowledge gained from both space and Earth based instruments. Many of these missions are characterized by comparatively low Earth orbits and high data rates.

Ms. Kelly provided a chart showing two types of programs: large observatories and smaller targeted missions. Most have planned launch dates between now and 2003. Large observatories generally use data relay satellites for telemetry capture while smaller missions are frequently supported by small, dedicated ground stations. Recently, consideration has been given to dumping data from large observatories directly to the ground because of the significant advantage in G/T performance enjoyed by ground stations over data relay satellites. Both types of missions employ the same operations and control center.

Ms. Kelly observed that Earth Science missions have not considered the SLE interface because their data transfer involves only bits and a clock. Some missions are CCSDS compatible on the space link while others are not. She noted that the Committee for Earth Observation Satellites (CEOS) is the primary vehicle for promoting international cooperation and is investigating standard interfaces.

The NASA Earth Sciences presentation concluded by noting that the X-band frequency allocation at 8025-8400 MHz is becoming crowded and that consideration should be given to moving these missions to K_A-band. For data transport between ground facilities, NISN has an activity to convert the clock and data interface to IP. Finally, CEOS participation in the group for ground system interoperability should be encouraged.

Ms. Kelly's presentation can be found in the Section entitled: *Future Collaborative Missions.*

3.4 Discussions Following Future Collaborative Missions Presentations

This discussion session was intended to promote the exchange of ideas among persons attending the Interoperability Plenary. The following summarizes the points made by the various representatives.

1. CCSDS space link standards are utilized by most agencies facilitating interoperability.
2. Within the Space Science community, the SLE interface is generally accepted.
3. One advantage of a single, uniform interface will be to facilitate integration and testing.
4. The CCSDS is the appropriate organization to develop data handling standards for the international space agencies.
5. Concern was expressed that the Earth Science community and CCSDS have not investigated the application of CCSDS standards to Earth Science missions in order to achieve greater interoperability. A closer tie between these groups was encouraged.
6. Concern was expressed that the Earth Science community has not investigated a broader application of CCSDS standards in order to achieve greater interoperability.
7. There was a consensus that CCSDS should work with CEOS to adopt the SLE interface and to assist the Earth Sciences community in the SLE's development and implementation.

4.0 ARCHITECTURE FOR INTEROPERABILITY - Wallace Tai

International agreement on only two areas is all that remains to achieve full interoperability. First, agreement is needed on the interface protocol at the *Applications Layer.* Second, the transmission protocol at the *Network Layer* should be specified.

The CCSDS has adopted recommendations for the Space Link Extension (SLE) interface and several of its included services addressing the first area above. Mr. Tai's presentation described that interface.

A fundamental architectural requirement is to provide a common interface solution for all agencies and for all missions. Moreover, the architecture applicable to the ground segment must be consistent with end-to-end interoperability. To ensure maximum flexibility and minimum cost when changes are necessary, a "layered approach" should be used permitting modifications within one layer which will not affect other layers.

Mr. Tai presented a diagram showing the several interfaces and highlighting the ground system interface now under discussion. From this diagram and a layered view of the space operations services, it is possible to derive a set of characteristics for an interoperable communications system. These characteristics define a core set of services, which should be initially implemented by space agencies to ensure ground system interoperability.

Mr. Tai's presentation can be found in the Section entitled: *Architecture for Interoperability.*

4.1 Discussions Following Architecture for Interoperability Presentation

1. At the minimum, four basic services should be implemented at the outset; Telecommand (CLTU, FSP) and Telemetry (RAF, RCF).
2. The CCSDS should be encouraged to specify a core set of Management Services needed to facilitate operations of the services in 1 above.
3. Services for the exchange of radio metric data should be the next priority. The CCSDS should be asked to consider both the Spacecraft-Planet Kernel (SPK) and the Orbit Data File (ODF) for the exchange of trajectory and pre-solution radio metric data respectively, to determine whether these can serve as interim or final standards.
4. It is impractical, in most cases, to permit an investigator to have direct access in order to send commands to a spacecraft. Safety checking by a central mission system is required.
5. The Applications Layer is important to interoperability and the SLE interface provides that capability.
6. Within NASA, there is still a debate on the suitability of IP for the space link. Several issues were identified: IP is not RF bandwidth efficient, IP will not operate well with long round-trip-times (RTLT), and IP is not satisfactory where multiple sessions are needed, but only for single sessions having short RTLTs.
7. The CCSDS should be asked to investigate specification of a transmission protocol at the *Network Layer*.

5.0 IN-PLACE STANDARDS - Adrian Hooke

To date, the focus has been principally on the Space Link (SL). This was necessary because the CCSDS had limited resources and the SL was the more important. After 10 years, these standards are now well accepted by virtually all space agencies. However, telemetry still operates in a "send-and-pray" mode. To date there is no telemetry counterpart to the closed-loop telecommand protocols. However, Mr. Hooke noted that the CCSDS Packet protocol is an Internet protocol, which has been optimized to use the space link efficiently.

Second generation CCSDS standards seek to remedy this deficiency. The Space Communications Protocol????? (SCPS) enables end-to-end connectivity. Now a CCSDS Blue Book, SCPS provides a capability to transfer files (FTP), a transport protocol (Internet TCP-UDP), an Authentication Layer for security, and a Network protocol. Continuous "Telescience" and end-to-end connectivity, in a TCP/IP like mode, are possible with CCSDS SCPS.

Where multiple session operations are required, the CCSDS File Delivery Protocol (CFDP) should be used. Not only does CFDP provide reliable file delivery, but it also permits custody transfers while maintaining a point-to-point space link.

Mr. Hooke then presented a diagram showing an end-to-end system showing the layering at each interface from instrument to end-user. It showed how to extend the Internet to space applications. The presentation concluded with a set of slides showing how SCPS can support Telescience, Store and Forward, and Streaming Science applications which, when coupled with the SLE interface, can make international cross-support a reality. Mr. Hooke emphasized that the next areas of work for the CCSDS will be to define a core set of Management, Mission Control, and 2nd generation SLA services.

Mr. Hooke's presentation can be found in the Section entitled: *In-Place Standards.*

5.1 Discussions Following In-Place Standards Presentations

1. SCPS is an Internet-like protocol permitting end-to-end telescience operations, which are time disjoint.
2. Asynchronous Transfer Mode (ATM) operations may be possible but will not efficiently use the space link because of the requirement for continuous connectivity and high overhead.
3. Very few missions require a "joy-stick" operational mode and some agencies would prohibit that sort of operation entirely because it is both risky and expensive.
4. A major problem in the past is lack of system performance accountability in ground stations. The SLE interface, and associated services, can remedy this deficiency.
5. Unlike present interfaces, the SLE wraps protocols, which have not been terminated at the ground station, with additional information needed for processing and sends them to a central location. It provides the same capability in the reverse direction for commands.
6. The SLE interface, which is at the Applications layer, resides above any Network protocol including TCP/IP. TCP/IP is baselined by many agencies.

7. To obtain the maximum interoperability benefit from the SLE interface, the initial services to be implemented by each agency are: CLTU, FSP, RAF, and RCF.

8. The CCSDS has begun work on the Management services. When complete, it will permit end-to-end automated operations. After the first set is completed in 6-9 months, they can begin work on Mission Control services.

9. The discussions identified an issue: Is it necessary to implement the SLE interface at the stations or is it sufficient to provide it at a central location for each agency?

6.0 SUMMARY OF PLENARY PROCEEDINGS AND DISCUSSIONS

At this time, all of the presentations and discussions pertaining to ground system interoperability were completed. The Agenda called for agency representatives to form some conclusions based upon what they had heard and to determine whether or not the Plenary's objectives had been met. Mr. Dale asked Nicholas Bobrinsky to determine if there was a consensus among the agencies represented at the Plenary.

6.1 Development of Agency Positions - Nicholas Bobrinsky

Mr. Bobrinsky noted that several points needed to be addressed by each agency including:

1. Is your agency committed to interoperability?
2. What is the baseline interoperability scenario that should be applied in interface design?
3. What is your agency's planned methodology of implementation including capabilities?
4. What is your schedule for implementing the recommended interface?
5. Do you have an interim interface to be used until the general solution is in place?
6. Do you believe that Management services are needed?

Mr. Bobrinsky suggested that the Interoperability Plenary meeting be adjourned for about 45 minutes to permit agencies to caucus and develop their set of answers to these questions. Results would be reported to the Plenary.

The following table summarizes each agency's response to the specific questions enumerated above. Numbers at the top of the table correspond to those of the question.

AGENCY	1	2	3	4	5	6
ESA	Yes	CCSDS Blue Books	RAF, RCF, CLTU, FSP	Integral, Mars Express	NDIU, Protocol Conv.	Agencies to document their services/costs
DLR	Yes	CCSDS Red/Blue Books	CLTU, RAF	CLTU - Available RAF- Under study	Protocol Conv.	CCSDS
NASDA	Yes	CCSDS	No plans	No plans	SELENA Implementation	No idea
ISAS	Yes	CCSDS Blue Books	CLTU, RAF evolve to FSP, RCF	Partial SLE by 2002, full SLE 2009	SLE by gateway evolving to no gateway	Standardize on CCSDS Red Book in Nov. 99
ASI	Yes	TBD but probably CCSDS	Feasibility study in next 6 months	TBD	TBD	TBD
CNES	Yes	CCSDS Blue Books	CLTU, RAF	SLE in 4 yrs.	NDIU, Gateways	TBD-Frame Agreements
NASA	Yes	CCSDS Blue Books	Prototype test: CLTU, RAF, FSP, RCF	Integral: RAF, RCF, CLTU, FSP, ODF, SPK	DSN: Integral GN: Solar-B SN: TBD	Mission driven. IAG determined

6.2 Agency Consensus - Nicholas Bobrinsky

Following the individual agency responses, Mr. Bobrinsky prepared a composite summary of the agencies' findings. The following represents the consensus of all agencies at the Interoperability Plenary meeting.

1. All agencies are committed to becoming interoperable.
2. Agencies believe that the CCSDS is the proper forum to decide technical issues. ITCOPs are the correct group for administrative and management issues as well as for coordination.
3. DLR, ISAS, CNES, ESA, and NASA all believe that the SLE interface with RAF and CLTU services is the correct one. ASI will conduct a feasibility study. NASDA has no plans for SLE at this time.
4. Implementation schedules should be missions driven. Missions such as Integral, Rosetta, Mars Express, Solar-B, and MUSES-C are drivers. Most agencies will implement the SLE *service user* function before they will build the SLE *service provider* function.
5. Interim solutions include principally NDIUs, protocol converters, and an early set of SLE services.
6. Today, Management services consist of a set of bilateral agreements. In the future, a CCSDS standard should be agreed allowing most agencies to implement the required functions in a coherent way.
7. There was a consensus that an Interagency Advisory Group (IAG) for space communications should be formed.

6.3 Wrap-Up Session - All

1. Agencies should provide guidance to the CCSDS to assist in prioritizing their standards development (R. Miller). The Plenary concluded that Agencies should provide this guidance through the existing Inter-Agency Coordination Group (IACG) Working Group-4 (WG-4) and by various Inter-Agency Tracking, Communications, and Operations Panels (ITCOPs).
2. CCSDS should be encouraged to update standards in other areas such as radio metrics so as to provide SLE service specifications in commonly needed areas (P. Maldari).
3. Agencies need to make sure that the CCSDS resources are used efficiently (CNES).
4. A multilateral Interagency Advisory Group (IAG) for space communications should be formed so that all agencies are represented in a single forum. It should undertake the task of negotiating many of the issues presented at this Interoperability Plenary Meeting (Group).
5. Would the IAG replace the bilateral groups (D. Dale)?
6. Bilateral groups could continue but there may be a need for an oversight group to provide direction to development groups (R. Spearing).
7. Once the IAG is formed, what will be its relationship to other groups such as the IACG (unknown).

8. The IAG should not meet on a specific schedule. Rather, their meetings should be tied to events such as a mission need (D. Dale).
9. SLE services development should be driven by mission needs and there should be no deviation from those established for the current implementation. A person responsible for working within the group should not deviate from previously agreed specifications without the prior permission of the multilateral working group (P. Maldari).
10. Someone should be responsible for monitoring the entire process and the multilateral IAG is the right one (R. Spearing).
11. R. Spearing accepted the responsibility for taking the lead in establishing the IAG and will prepare a draft charter.
12. Agencies should investigate the possibility and cost benefit of each developing a subset of APIs and then exchanging these with other implementing agencies.

7.0 VIEW 0F THE FUTURE - Adrian Hooke

The first Interoperability Plenary Meeting concluded with a presentation by Adrian Hooke highlighting the changing nature of international interoperability. Among the many trends driving these changes are:

1. Commercial ground networks.
2. Commercial communications providers.
3. New, higher RF operating frequencies.
4. Automated operations for stations and control centers.
5. Bulk file transfers and Internet-like operations.
6. In-situ operations of landed vehicles using proximity links.

The Mars program, in which many agencies present at the Interoperability Plenary are interested, will provide the ultimate test for inter-agency interoperability. Because of its size and complexity, that program requires international cooperation and hence efficient interoperability.

Fortunately, recent CCSDS standards for the Proximity Link and File Transfer protocols are directly applicable to the Mars Program and should be used as a basis for interoperability. The first decade of the next millennium should see most of the items listed above becoming an operational reality. However, to ensure that the development of new standards matches the needs of new space missions, mission designers should work closely with the CCSDS to ensure that their requirements are understood.

Mr. Hooke's presentation can be found in the Section entitled: *View of the Future*.

8.0 FINAL AGENCY REMARKS

At the conclusion of the Interoperability Plenary Meeting, each agency was asked to make a final statement. Their remarks follow.

1. ISAS

Representatives to the Interoperability Plenary Meeting should consider how IACG Working Group-4 could assist in implementing the results of this meeting.

2. NASDA

NASDA is pleased with the Action Items and would like to contribute to SLE standardization in the future.

3. DLR

DLR is pleased with the high level of cooperation at this meeting and it is looking forward to replacing converters used for agency interfaces in the past with a new and stable SLE interface standard. However, when true interoperability is achieved, these systems will need to be exercised periodically to ensure that they can provide proper, timely emergency support.

4. ASI

ASI stated that it was very pleased with the outcome of this meeting.

5. CNES

CNES was also pleased with the Plenary Meeting's results and hoped that it will improve operational efficiencies.

6. ESA

Interoperability is very much on the agenda throughout Europe. Budget constraints dictate the sharing of facilities to reduce operating costs. ESA sees nothing but benefits from this meeting but cautions that there have been many standards activities that have not succeeded in the past. ESA hopes that IACG Working Group-4 can provide the needed impetus for ensuring that the SLE interface achieves interagency interoperability.

7. NASA

Mission traffic dictates both interoperability and standardization. Future budgets will not permit a "business-as-usual" attitude and it will be management's responsibility to get the job done.

MINUTES OF THE INTEROPERABILITY PLENARY MEETING

ACTION ITEMS

1. Determine whether SLE interface implementation costs can be reduced if each agency develops a subset of APIs and then shares them with the other agencies.

2. Each agency should contact their Earth Sciences organization to determine whether:
   a) CEOS has standards applicable to the ground system interfacing;
   b) The CEOS solution is applicable to other mission types;
   c) An SLE interface should be used for Earth Sciences missions.

3. Agencies to prioritize a set of Management procedures to be implemented for cross-support interoperability. These will be placed in the Terms of Reference for the new Interoperability Advisory Group (IAG) for space communications.

4. Based on CCSDS definitions, Agencies to identify the services that they will provide for cross-support and the costs therefore.

5. NASA to provide a draft Terms of Reference for the new Interagency Advisory Group (IAG) for space communications.