The IOAG Recommendations On Spacecraft Emergency Cross Support*

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In 2014, the Inter-agency Operations Advisory Group (IOAG) chartered a multi-agency team effort to study how to best handle spacecraft emergency as part of cross support among network assets. The original intent is to put in place for the first time a process and guidelines to make emergency support as part of a permanent cross-support capability between space agencies. From the perspective of space communications service providers, a few key issues, common to all agencies, concerning the Spacecraft Emergency Cross Support (SECS) have been explored. They are: context of emergency support, provision of emergency support under a cross-support agreement, provision of emergency support with no cross-support agreement, legal and liability issues, response time, support priority, services provided, sustaining emergency support capabilities, and charge for the support. The positions of the various participating agencies with respect to these issues have been collected, analyzed, and finally harmonized to form the recommended IOAG positions.

A central challenge most communications service providers are facing is that since the spacecraft emergency is an unplanned critical event, it typically requires fast response to the emergency call, hence lacking an international standard process for the operational interfaces seems to exacerbate the difficulty in providing SECS. For reducing the response time, i.e. from the time of accepting a request for SECS to the readiness for support, it is recommended that a "cross-support emergency system" be established by IOAG member agencies. Along with it, the IOAG core services, just-in-time ground communications line, cross support service management (CSSM), and standard operations procedures (SOP) for operational interfaces form the basic foundation of the "cross support emergency system". Of the above, new to the cross support conducted thus far in the IOAG community is the concept of the SOP specifically for the interfaces between the service provider and service user during the SECS. Use cases, salient features, and definition of the key operational activities/tasks relevant to the interfaces are addressed by the effort.

Underpinning such a system is the availability of the RF license granted by the local authority, at national and/or regional level, for a given ground station to communicate with and track the spacecraft in emergency mode at the uplink and downlink frequencies assigned to that spacecraft. That means it is critical for the IOAG member agencies to obtain *a priori* all-band licenses (for the entire X-band or S-band) for some, if not all, of their ground stations that are most capable of or likely to provide SECS. It is also recommended that certain prior arrangements be made with the relevant local licensing authorities for a process that will allow expedited authorization to transmit/receive signals to/from the declared spacecraft over the declared ground stations specifically and solely for the emergency case.

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Our analysis of the SECS has also uncovered a few fundamental programmatic issues. Recognizing any IOAG positions reached on these issues do not necessarily lead to any binding authority, it is recommended that they, along with those key attributes of the cross support emergency system, be explicitly stated as multi-agency guidelines to guide the implementation and provision of the SECS.

The paper will present the results of the working group on Spacecraft Emergency Cross Support and, in particular, its findings, products and recommendations. It will also identify the next steps of this work that may include the production of some international standards as an extension of this work, or the process to make this emergency system usable by other spacecraft operators beyond the space agencies.

I. Introduction

THE Spacecraft Emergency Cross Support Working Groups (SECSWG) has been installed during the Interagency Operations Advisory Group[1] meeting IOAG-18 in February 2014, based on a recommendation that was made at the Inter Operability Plenary-3 (IOP-3)[2,3]. The objective is to establish a common, standard process, agreed upon by the IOAG member agencies, for providing spacecraft emergency cross support (SECS).

At the beginning of the working group effort, two categories of spacecraft emergency cross support were identified: one which has existing bilateral agreements (for TT&C support), and the other with no existing bilateral agreement. The main intent of a concerted emergency cross-support effort is to define standard operation procedures (SOP) and interface guidelines in order to facilitate emergency support, especially in the context of cross-support where no agreement exists. For instance, the requesting agency may require emergency contacts to be conducted through antennas from a supporting agency. With the provision of predefined interface standards, it is possible for the supporting agency to be readily technically compliant with the mission in order to allow support under short notice and without having to undergo significant engineering changes. Also, with the establishment of agreed upon standard operation procedures, both the mission and the station operators would have the procedural tools to engage formally with the request and conduct the support.

II. Background

As part of its main activity, the SECSWG is to regularly interact in order to establish a common, standard process, agreed upon by the IOAG member agencies, for providing spacecraft emergency cross support[4].

The main activity breaks down into:

1) Identify the specific problem(s), weakness/deficiency, and/or areas for improvement in the inter-agency emergency cross support, past and present.
2) Define the <u>operational process</u> executed by both the service provider and service users in time of the spacecraft emergency. Focus on the standardization, enhancements, and preparedness of the communications and navigation <u>operational activities</u>.
3) Define the <u>common policy</u> that governs emergency cross support agreements among the IOAG member agencies. The policy statements shall cover at least support priorities, constraints (e.g. uplink RF licenses), and programmatic accountability.
4) Identify the key characteristics of the relevant CCSDS cross support services, needed for interoperability, that are unique to spacecraft emergency cross support. Assess these characteristics to determine potential new requirements and/or interfaces for the service providers and service users to comply.

In that scope, the SECSWG is to provide a report of findings to the face-to-face meeting of the IOAG, which can be discussed with the various agencies. This paper reflects the findings, recommendations, and conclusions of the study as documented in the report.

III. Problems of The Current Spacecraft Emergency Cross Support

One main topic of the SECSWG, as stated in its statement of work is to "identify the specific problem(s), weakness/deficiency, and/or areas for improvement in the inter-agency emergency cross support, past and present".

Main problems IOAG member agencies encountered in the current practices of SECS are:

1) <u>How to assure the timely availability of uplink and downlink authorizations for SECS?</u>
   Valid uplink and downlink authorizations are prerequisites for SECS. For uplink authorizations RF uplink license applications need to be filed and approved by the responsible national/local authorities while

downlink authorization applications need to be filed and approved by the ITU. Downlink authorization applications are standardized by the ITU for all ITU member states, nevertheless it is, by its nature, a time consuming process. For RF uplink license applications we have a diverse situation due to the responsibility of national/local authorities. Particular for cases where the SECS are provided to missions without existing bi-lateral agreements between the two agencies, this has mainly implications on the timely availability and costs depending on the responsible national/local authority.

2) How to ensure the SECS be conducted in an expedited, timely, and orderly manner?
Spacecraft emergency is an unplanned event. It is a rare event. And the need for potential SECS by communication assets of other agencies very often is under-estimated and not predicted. A common phenomenon in the current practices is that it sometimes tends to take an intense, frantic, and heroic effort at both provider and user sides to conduct the SECS operations, and, with huge difficulty, to provide the expedited, timely support needed by the spacecraft. The situation is worse in those instances where there is no existing bi-lateral agreement between the two agencies.

To overcome the encountered problems, some recommended solutions, as described in detail in Section V, have been proposed.

IV. Key Issues Concerning The SECS

The SECSWG has been working on the following identified key issues:

1) Context of spacecraft emergency cross support (SECS)
2) Providing emergency support under a cross-support agreement
3) Providing emergency support with no cross-support agreement
4) Legal and liability issues
5) Response time
6) Support priority
7) Services provided
8) Sustaining emergency support capabilities
9) Charge for the support

The SECSWG's understanding of each of these items and related aspects discussed are outlined here. Actual recommendations related to each key issue are presented in Section V.

A. Context of Spacecraft Emergency Cross Support

Spacecraft emergency has been understood and defined as the state caused by the occurrence of an anomaly in the spacecraft, including the safety of spacecraft or failure of a spacecraft component, that, if not corrected, will result in the spacecraft's inability to meet the mission objectives. In addition, for human space flight missions, any external or internal conditions that could negatively affect the health and safety of the crew are causes for spacecraft emergency mode.

A spacecraft emergency mode might result in the need for SECS. The responsibility for initiating and obtaining cross support by ground stations owned by other agencies and for replanning the overall spacecraft operations remains with the operating agency of the spacecraft.

The SECS capabilities are about providing TT&C support to restore the spacecraft health to a normal state, therefore, not for ensuring mission data return. The duration for emergency cross support will be negotiated between the service provider and service user as the recovery action progresses.

B. Providing Emergency Support Under A Cross-Support Agreement

The current IOAG Service Catalog does not treat the SECS as a type of service. While we do not suggest the SECS be a separate type of service and we believe it should be viewed as the inherent part of the return data/forward data/radiometric services, we do recommend the SECS be explicitly identified as a special mode, i.e., emergency mode vs. nominal operational mode, in the Service Catalog for these. The emergency mode deserves certain attention since operationally special actions must be taken. These may include, for instance, wider antenna sweeping to achieve initial acquisition of uplink signal by the spacecraft, modulation index manipulation for command bit lock by the spacecraft, and special low-rate telemetry for data acquisition by the ground station.

The SECS very often is not explicitly stated as a requirement in support agreements. This has led to certain deficiencies in time of support. It is recommended that the SECS requirements be explicitly specified in the service agreement. Moreover, the IOAG should define certain standard functional and performance attributes governing the SECS.

C. Providing Emergency Support With No Cross-Support Agreement

Providing emergency support to a mission with no existing cross support agreement has indeed happened from time to time. Although atypical, such a case is not unusual or unexpected. After all, spacecraft emergency is an unplanned event. And the need for potential SECS by communication assets of other agencies very often is under-estimated and not predicted.

In this case, the current practices in SECS can be characterized as follows:

1) The provider has no prior knowledge about the link configuration and mission profiles. Hence, the SECS rendered is without any planning, preparation, or being test qualified (let alone proficiency testing). Based on a set of minimum number of uplink/downlink parameters provided by the user mission, impromptu, but time-consuming configuration set-up at the ground stations demands intense and heroic effort on both provider and user mission sides. Of course, delay to set up configurations throughout the ground station is to be expected.
2) Since obtaining pertinent RF license and/or the authorization to use certain frequencies to support the spacecraft in emergency can take a few months of paper work, in order to rescue the spacecraft, the provider tends to forego the RF licensing and authorization process that are normally followed by both agencies. After all, the deed (or misdeed) is for a noble cause!
3) The service would be on a best effort basis with no obligations to meet the last-minute support "request". The service would be supported on individual mission basis, not necessarily according to priority rules.

It is recognized that the current practices can be further improved based on the recommendations from the study.

D. Legal and Liability Issues

For the SECS, the supporting agency shall not be held liable for any consequential damages resulting from its actions. That also means any supporting agency does not have to guarantee the availability and readiness of its tracking facilities for the support.

All space agencies must respect the ITU regulations for the RF license. Therefore, it is recommended that each agency that would potentially require SECS must provide the ITU with filing information of the supported spacecraft. Moreover, agencies that are required to provide SECS must apply for a license, through their local licensing authorities, for the declared spacecraft over the declared ground stations. We further recommend that the IOAG member agencies negotiate certain arrangements with the relevant local licensing authorities specifically for the emergency case. In that regard, an *a priori licensing* scheme is proposed.

E. Response Time

For expediting the response to the SECS request, it is proposed that the IOAG member agencies set up a cross-support emergency system that can be invoked in case of spacecraft emergency. For this the following is needed:

Each agency should define an Emergency Contact Point. The Emergency Contact Point is designated as a single 24x7 operator phone number (hot-line) to call in case of emergency. Any need to contact other levels of support will be redirected from this line by the operator.

Upon reception of a call or request for SECS, the service provider should be able to follow up the request within 15 min with an acknowledgment and an initial estimate on the time of readiness for SECS. In the case where the request is too complex to be answered by the operator, the service provider will provide instead a time estimate for further request assessment.

The hot-line phone number of each Emergency Contact Point will only be distributed to the IOAG member agencies. It is a safeguarded data item.

F. Support Priority

Each agency has similar priority rules and the following only lists the ones relevant for SECS. It is proposed that the IOAG member agencies providing SECS shall apply the following support priority:

Priority 1: Emergency with astronauts affected

Priority 2: Emergency during the launch and early orbit phase (LEOP) after the separation of spacecraft from the launch vehicle

Priority 3: Spacecraft emergency for missions with bi-lateral agreements

Priority 4: Spacecraft emergency for missions with no bi-lateral agreements.

G. Services Provided

At present, all the IOAG member agencies have utilized (or intend to utilize) the core services as defined in the IOAG Service Catalog #1 to provide SECS. For providing and utilizing such services, it is imperative that the

underlying ground-to-ground communication lines are in place. Therefore, we recommend the IOAG define a simple way to quickly establish or acquire communication lines so that in time of emergency need this pre-requisite condition will not become a bottleneck.

It is recommended that the IOAG member agencies be prepared to implement and operate the standard service management functions as the CSSM standards become available. It must be noted here that the CCSDS Simple Schedule Format being the first standard in the CSSM series, if implemented by the various agencies, will represent a long way toward more expeditious, interoperable SECS.

There is a lack of standard operational interfaces at process-level and/or procedural level. The IOAG Service Catalog lists a number of individual services such as telemetry and telecommanding services but does not address those operational activities to be conducted cooperatively between the service provider and service user. Such a deficiency becomes more pronounced in the event of requesting, invoking, and coordinating SECS. It is recommended that the IOAG consider adding to the Service Catalog the standard operational processes/procedures critical to the SECS.

Furthermore, for providing the SECS to those missions without prior bi-lateral cross support agreement, it is recommended that IOAG establish some multi-agency guidelines so that its member agencies could support each other in time of spacecraft emergency.

In that same vein, the IOAG should assess whether it is beneficial and feasible to emplace a multi-agency triage function for such use cases. An alternative solution is to establish a bi-lateral, standing agreement specific for SECS between two IOAG member agencies regardless whether there exists a bi-lateral support agreement for a given mission.

H. Sustaining Emergency Support Capabilities

The SECS capabilities must be sustained by the participating agencies. By sustainment, it is meant to cover the following key elements:

1) The TT&C service capabilities relevant to the SECS, as discussed in Section G of IV: None of the standard SLE interfaces is unique to the SECS. Nevertheless, there is some SECS-specific, mission-unique configuration set-up that must be retained, controlled, and kept up-to-date for a potential mission.
2) The SOP for the SECS provider and user interfaces: The SOP, given its multi-agency ramifications, must be under change control by the IOAG. The SOP will also be improved, enhanced, and upgraded from time to time by the IOAG. Subsequent implementation by each member agency for the upgraded SOP will have to be somewhat orchestrated with its user missions community.
3) The operational proficiency in SECS: As the spacecraft emergency events are quite rare, the SECS capabilities deployed at the potential provider sites (or communication assets) could become rusty after some time period. Operationally, this may imposes a potential risk. To mitigate the risk, conducting proficiency tests on a period basis must be a common, standard practice.
4) The IOAG databases relevant to the SECS: There are some information databases established by the IOAG for assisting the SECS operations, as discussed in Section C of V. The accessibility to such information bases must be ensured by the IOAG. Moreover, since the information parameters associated with an RF asset and mission are provided by the individual agency. Any updates will have to be notified to the entire IOAG community via an explicit, clear mechanism.

I. Charge For The Support

In general the rule is a payment of the provided services; whether there was a prior cross support agreement or not.

The services and the way they are charged are most of the time defined under the terms of bi-lateral agreements. This will continue, in particular for missions of sensitive nature or for those requiring a more guaranteed support.

As a further step towards a more integrated international service, in particular to improve the unsubscribed cases, the IOAG could explore the possibility to establish an IOAG multi-lateral guideline by which all agencies agree to provide and receive services as per the definitions of liability, services, response time and support priority in the present document. Under these global and reciprocal arrangements, the actual emergency services could just be accounted in a ledger for exchanges of services, with the option to make them payable in case the situation becomes very unbalanced".

V. Key Solutions To The Current SECS Problems

A. RF License

All space agencies must respect the ITU regulations on allocation and declaration of use of frequencies even in case of spacecraft emergency. Therefore, it is recommended that each agency that would potentially require SECS must include the potential SECS station(s) of other IOAG members in the ITU filing of the agency's spacecraft. Moreover, agencies that are expected to provide SECS must apply for a license, through their local licensing authorities, for the requesting, declared spacecraft over the declared ground stations. IOAG further recommends that the IOAG member agencies negotiate when possible certain arrangements with the relevant local licensing authorities specifically for the emergency case. In any case, an *a priori licensing* scheme is to be followed for purpose of SECS.

The SECS Working Group proposes the *a priori licensing* scheme to achieve the need for timely availability of RF licenses at the supporting agencies for the SECS. The scheme features:

- All agreed communications assets potentially needed by a mission for the SECS are licensed in advance to use the frequencies to support that subject mission.
- The subject mission is pre-approved by the provider agency, in terms of its support by these communications assets in time of spacecraft emergency.

A possible scenario exemplifying this scheme is as follows:

1. During the mission formulation phase, when a mission, say Mission X, of Agency A submits advance publication and notification filings to the ITU, it includes in the ITU filings the communications assets (say Station Y of another IOAG agency, Agency B) that are potentially needed for the SECS. [Note: For missions already in flight, the same process applies, although limited to the notification filing.]
2. Agency A informs Agency B of such a potential need for SECS by Station Y for Mission X.
3. Agency B grants the approval based on the IOAG multi-agency SECS guidelines.
4. Agency B spectrum management submits a Radio Frequency Authorization (RFA) to its national and/or local RF licensing agency for approving Station Y to use the frequencies to support Mission X.

Fig. 1 illustrates the *a priori licensing* scheme for timely availability of RF license.

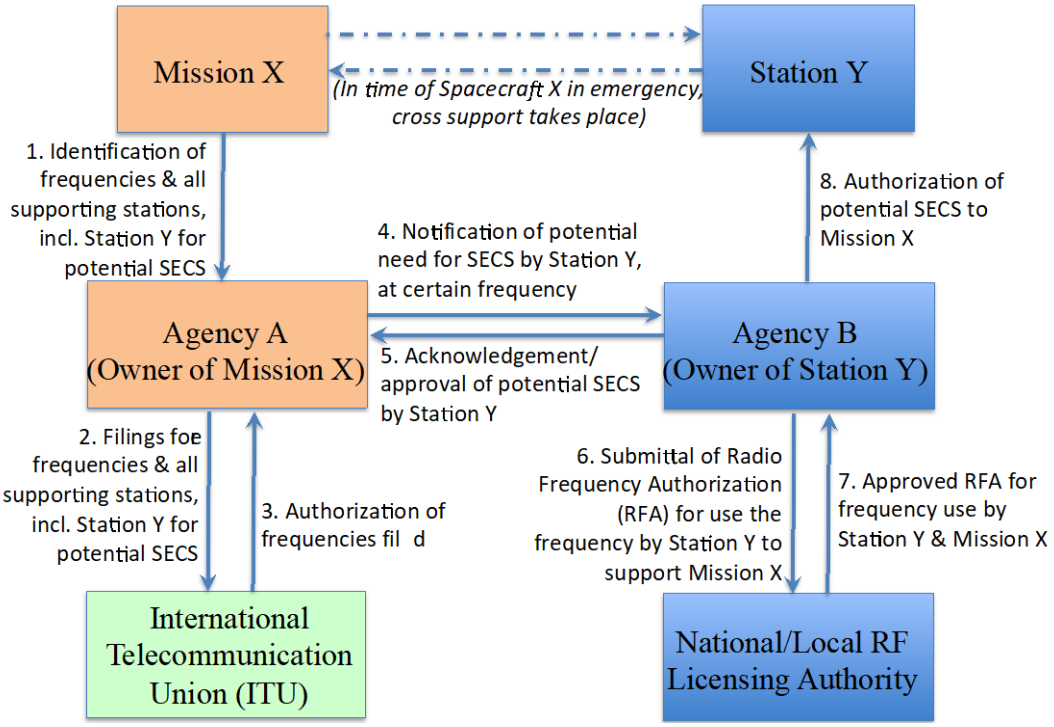

Figure 1. The *a priori RF Licensing* Scheme – The Scenario

The advantages of this approach are:

- Timely availability of RF license at the SECS service providing assets; no last minute panic.
- The process does not require bi-lateral cross support agreement between agencies for a given user mission.
- Minimal overhead and some added cost for the ITU filings and the RF license applications on both sides. RF license fees vary among the licensing authorities, but they do not seem to impose unbearable burden to the supporting agencies.

The disadvantages are:

- Potential missions and communication assets need to be identified and agreed between agencies in advance for this scheme.
- The whole scheme is predicated upon honoring the IOAG multi-agency SECS guidelines, on the part of supporting agency, in Step 3 above. This may be viewed as a "limitation" of the scheme to the requesting agency.

B. Participating Communications Assets in SECS

Identifying the communication assets available for SECS is necessary in order for each potential provider agency to enter into organizational commitment and take necessary preparatory actions to address the followings.

(a) The *a priori* licensing scheme

(b) Upfront engineering set-up for asset configuration

The RF licensing process involves official procedures for both ITU filings and uplink license applications to national/local authorities. For some agencies, upfront engineering set-ups, which may involve certain cost, are needed in advance.

For this reason, SECSWG is currently conducting a preliminary survey to narrow down the prospective communications assets capable of offering an effective emergency support, and this section addresses how the communications assets, to be used in the context of SECS, are identified.

The preliminary survey creates a matrix table that shows, at one view, which communication asset can readily provide SECS services for a certain mission. The first step is that each IOAG member agency proposes their available ground-based TT&C resources. This potential assets list may show, if any, operational restrictions, e.g. assets are not operational around the clock. The asset information is categorized into the following three operational domains.

- Assets for near-earth missions below GEO
- Assets for near-earth missions on or beyond GEO within 2M km
- Assets for missions beyond 2M km or deep space missions

Table 1 shows locations of all communication assets proposed by the SECSWG member agencies.

The second step is that each member agency specifies which of their missions would be interested in using the SECS services, and which of assets would most effectively provide an emergency support to the missions. Selection of the assets by a given mission may be dependent on the following factors:

- Site location: how does the asset, relative to other assets, fit in to ensure the needed geometric coverage?
- Spectral bands: S-/X-band for near-earth missions or deep space X-band
- Capabilities: G/T, EIRP, etc.

Then, the potential provider agencies owning the assets of interest will examine whether their assets would be able to accommodate the requested missions and give feedback to the potential user agencies. In the course of feasibility studies at each agency and preliminary negotiations between potential providers and users, the matrix table will be verified.

In this process, some agencies that need to work on the upfront engineering set-up may estimate the cost required for the engineering work at each asset, based on the number of missions expected to accommodate at each asset as well as the number of the assets. Such provider agencies may need to gain agency-wide consensus to facilitate their internal decision-making processes, clarifying whether an equivalent benefit can be obtained from the SECS cooperation.

The completed matrix table will be regularly revisited and updated by reflecting changes in the status of potential user missions and/or the possible assets. Furthermore, the SECSWG will continue its efforts to extend the survey to IOAG observer agencies and non-member agencies.

Table 1 and Figure 2 show the potential IOAG Ground Communication Assets available for SECS. These assets are proposed by from ASI, CSA, CNES, DLR, JAXA and NASA, and more assets are to be added reflecting inputs from other agencies.

Table 1. Potential IOAG Ground Communication Assets Available for SECS

Agency	Size (M)	Asset Type	Location	band	S-UL	S-DL	X-UL	X-DL
ASI	10	NE	Malindi, KEN	S,X	O	O		O
	10	NE	Malindi, KEN	S	O	O		
CSA	10	NE	St-Hubert, CAN	S	O	O		
	10	NE	Saskatoon, CAN	S	O	O		
	13	NE	Gatineau, CAN	S,X	O	O		O
	13	NE	Prince-Albert, CAN	S,X	O	O		O
	13	NE	Prince-Albert, CAN	X				O
	13	NE	Inuvik, CAN	S,X	O	O		O
CNES	11	NE	Kourou, GUF	S	O	O		
	10	NE	Kerguelen Islands, FRA	S	O	O		
	11	NE	Aussaguel, FRA	S	O	O		
	6.4	NE	Aussaguel, FRA	S	O	O		
	12	NE	Hartebeesthoek, ZAF	S	O	O		
	13	NE	Kiruna, SWE	S,X	O	O		O
	13	NE	Inuvik, NT, CAN	S,X	O	O		O
DLR	15	NE	Weilheim, DEU	S	O	O		
	15	NE	Weilheim, DEU	S,X	O	O		O
	30	NE/DS	Weilheim, DEU	L,X				O
	7.3	NE	Neustrelitz, DEU	S,X	O	O		O
	7.3	NE	Neustrelitz, DEU	S,X	O	O		O
	7.3	NE	Neustrelitz, DEU	S,X		O		O
	9	NE	O'Higgins, CHL	S,X	O	O		O
	13	NE	Inuvik, NT, CAN	S,X	O	O		O

Agency	Size (M)	Asset Type	Location	band	S-UL	S-DL	X-UL	X-DL
ESA	15	NE	Kiruna, SWE	S,X	O	O		O
	13	NE	Kiruna, SWE	S,X	O	O		O
	15	NE	Kourou, GUF	S,X	O	O	O	O
	35	DS	Cebreros, ESP	X			O	O
	35	DS	New Norcia, AUS	S,X	O	O	O	O
	35	DS	Malargue, ARG	X			O	O
JAXA	10	NE	Katsuura, JPN	S	O	O		
	13	NE	Katsuura, JPN	S	O	O		
	20	NE	Katsuura, JPN	S,X	O	O		O
	10	NE	Masuda, JPN	S	O	O		
	10	NE	Okinawa, JPN	S	O	O		
	18	NE	Okinawa, JPN	S	O	O		
	10	NE	Mingenue, AUS	S	O	O		
	10	NE	Santiago, CHL	S	O	O		
	10	NE	Kiruna, SWE	S	O	O		
	10	NE	Maspalomas, ES	S	O	O		
	20	NE	Uchinoura, JPN	S,X	O	O		O
	34	NE/DS	Uchinoura, JPN	S,X	O	O	O	O
	11	NE	Uchinoura, JPN	S	O	O		
	64	DS	Usuda, JPN	S,X	O	O	O	O

Agency	Size (M)	Asset Type	Location	band	S-UL	S-DL	X-UL	X-DL
NASA	5	NE	Wallops Island, VA, USA	S	O	O		
	11.3	NE	Wallops Island, VA, USA	S,X	O	O		O
	10	NE	Fairbanks, AK, USA	S,X		O		O
	11.3	NE	Fairbanks, AK, USA	S,X	O	O		O
	18.3	NE	White Sands, NM, USA	S	O	O		
	70	DS	Canberra, AUS	S,X	O	O	O	O
	70	DS	Goldstone, CA, USA	S,X	O	O	O	O
	70	DS	Madrid, ESP	S,X	O	O	O	O
	34	NE/DS	Canberra, AUS	S,X	O	O	O	O
	34	NE/DS	Canberra, AUS	S,X	O	O	O	O
	34	NE/DS	Canberra, AUS	X			O	O
	34	NE/DS	Canberra, AUS	X			O	O
	34	NE/DS	Canberra, AUS	X			O	O
	34	NE/DS	Goldstone, CA, USA	S,X	O	O	O	O
	34	NE/DS	Goldstone, CA, USA	X			O	O
	34	NE/DS	Goldstone, CA, USA	X			O	O
	34	NE/DS	Goldstone, CA, USA	X			O	O
	34	NE/DS	Goldstone, CA, USA	S,X	O	O	O	O
	34	NE/DS	Madrid, ESP	S,X	O	O	O	O
	34	NE/DS	Madrid, ESP	X			O	O
	34	NE/DS	Madrid, ESP	X			O	O
	34	NE/DS	Madrid, ESP	X			O	O
	34	NE/DS	Madrid, ESP	S,X	O	O	O	O

Remarks:

NE for Near Earth mission
DS for Deep Space mission
with Restrictions (e.g. operation not around 24H, Highest priority to certain agency's missions)

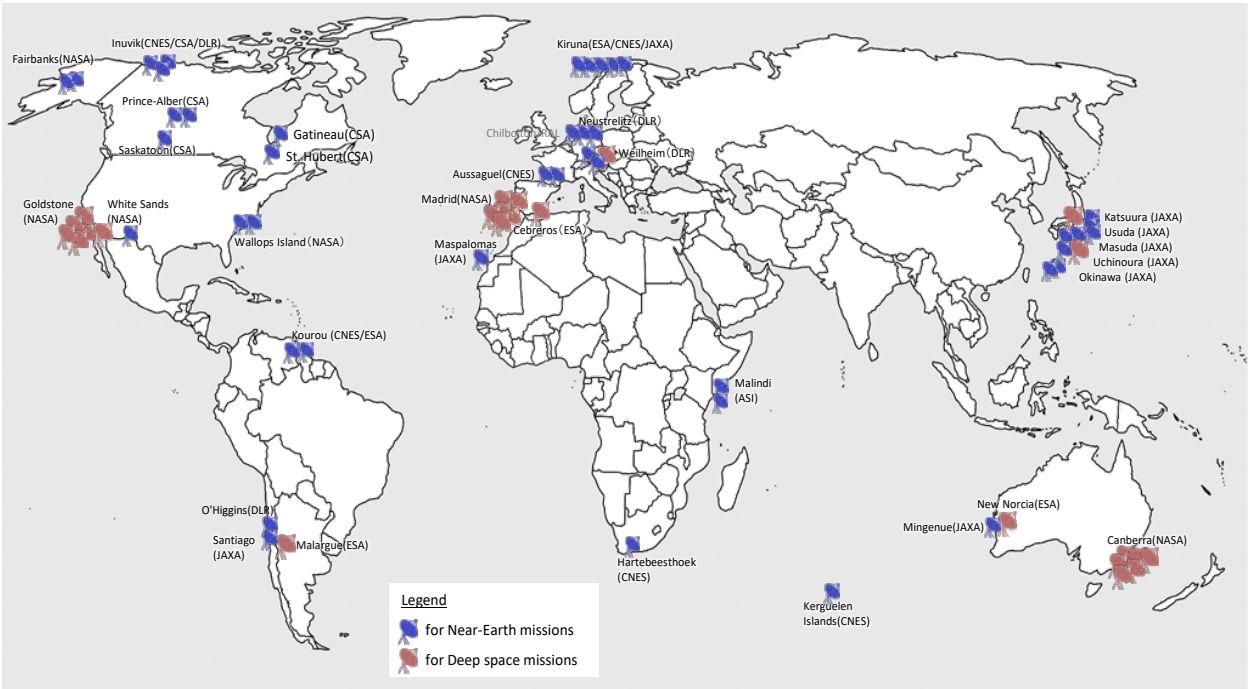

Figure 2. Potential IOAG Ground Communication Assets Available for SECS – A Global Sites Map

C. Standard Operations Process/Procedures (SOP)

The real challenge in the provision of an Emergency Support to a Spacecraft is the response time between the discovery of the Emergency situation and the availability of an asset to provide a support that, potentially, will allow to rescue the spacecraft and to restore a nominal situation. Several hours may be too long and the Emergency Cross Support is only meaningful if there are chances to provide a very quick answer. In regular cross supports, the Users and Providers of ground station services go thru phases of design and definition of the ground segment, implementation of configurations, tests and validations, or even rehearsals, to establish and qualify the services to be provided. In the case of an Emergency Cross Support with no prior preparation, all these steps must be completed within a very short timeframe, in a simplified way. And potentially, there are many ways to meet this objective, resulting in multiple practices among the IOAG Members.

The IOAG has identified from the very early stages of his work that there is a lack of standard operational interfaces at process-level and/or procedural level to facilitate and harmonize the practices between the User and the Provider of an Emergency Cross Support. It will be the objective of the Standard operations process / procedures (SOP) to elaborate on an IOAG recommended approach for such harmonized practices. In addition, the SOP will identify the tools that may be used in the near term and in the long term to implement the proposed procedures.

Therefore, the scope of the SOP has been defined as follows:

- The SOP is focused on the operational interfaces between the SECS service User and service Provider.
- It applies to the SECS provided to CCSDS-fully compliant missions only; otherwise limitations on services are quite likely.
- The services to be provided are those of the IOAG Service Catalog #1, mainly for telemetry and telecommanding.
- The SOP will be used by the IOAG Member agencies for SECS purpose, although the use cases can potentially be extendible to non-IOAG agencies in the future.
- In addition, the SOP may apply to the SECS provided to a mission regardless whether a bi-lateral service agreement exists or not.

For the purpose of achieving common, standard operational interfaces for the SECS, five relevant key processes have been defined, so far, at a conceptual level. They are addressed in the following sections, respectively with a near term and long term visions, to illustrate the technical directions to be followed in establishing the SOP specification, which activity remains to be completed at the IOAG level; That also means, for defining the real, executable processes, they will have to be further elaborated down to the procedure level and certain aspects of which be standardized.

1. Near-Term Approach

For each of the identified processes, some key considerations are reported that will be the basis for the procedures to be later developed in the IOAG SOP documentation.

<u>Process 1 Near-term. Selection of a Provider</u>

In the process for Selection of a Provider, the User will conduct his own evaluation based on the information already made available at his level, before contacting the Provider(s) he will find the most appropriate to render the service. His first concern will be to determine which assets from which Provider(s) may be used in support of his mission. This may be addressed with the following elements:

1) List of assets that the Providers are willing to propose for SECS;
2) Main characteristics of the assets, in particular, in terms of geographical locations, frequency bands and link budget parameters, ground to ground services and availability of a RF license to support the mission;
3) Availability of an initial point of contact (IPoC) of the Provider, to go further with the assessment.

The IOAG has identified the following tools to initially support the process:

1) A list of the participating communication assets has been established (cf. Section B above) and will be part of the initial procedure;

2a) The IOAG table with the communication assets, currently hosted under the SANA web site, will be upgraded to provide the minimal information required for the User to assess the adequacy of the assets to support a mission;

2b) A procedure for a priori licensing has been established (cf. Section A above) and will be part of the initial procedure;

3) The list of Initial Points of Contact (IPoC) will be part of the SOP document.

Process 2 Near-term. Assessment on Ability to Support

In the process for Assessment on Ability to Support, the User and the Provider need to exchange the minimum information required to assess the priority to be given to the ECS, to evaluate the response time and to confirm the ability to support. This aspect may be addressed with the following elements:

1) Priority list and characteristics of situations to classify the call as part of an ECS;
2) Orbit and predicted contact times;
3) Confirmation of the feasibility of the required support by the Provider, based on the availability of ground assets and of the supporting personnel, the validity of the RF license, the G/S compatibility, the existing communication line resources to provide the support and the G/G availability of services.

The IOAG has identified the following tools to initially support the process:

1) A priority list has been established by the IOAG with a definition of the cases recognized as Emergency situations, and this will be part of the initial procedure;

2) The IOAG Members will rely on the Orbit Data Message format of CCSDS to exchange on orbit and visibility predictions;

3a) The IOAG will define as part of the SOP the minimal set of mission configuration parameters to be submitted by the User to allow the Provider to assess the feasibility of the support to the concerned mission;

3b) A procedure for a priori licensing has been established (cf.Section A above) and will be part of the initial procedure;

3c) The IOAG will define in the SOP a simple procedure to quickly establish or acquire communication lines so that in time of emergency need this pre-requisite condition will not become a bottleneck.

Process 3 Near-term. Support Preparation

The process for Support Preparation is usually time consuming as it implies the setup of the required parameters on all the Provider's systems to be used in support of the ECS. It must be anticipated as much as possible by the provision of the required configuration parameters in advance to any actual call for an ECS. Contrary to the case of a regular cross support, there will be no test and validation phases of the setups, which means that this phase is very critical for the chances of success in the ECS.

The IOAG has identified the following tools to initially support the process:

1) The IOAG will define as part of the SOP the sufficient set of mission configuration parameters to be submitted by the User to allow the Provider to setup the configurations required for each of its supporting systems.

Process 4 Near-term. Pass Support

In the process for Pass Support execution, the User and the Provider need to exchange the information required to properly coordinate on the execution of the ECS. This may be addressed with the following elements:

1) Schedule information;
2) Trajectory information;
3) Pass execution procedure;
4) Possibility for support extensions.

The IOAG has identified the following tools to initially support the process:

1) The IOAG Members will initially use the standard outputs of their scheduling systems to reflect the committed activities;

2) The IOAG Members will rely on the Orbit Data Message format of CCSDS to exchange on orbit and visibility predictions;

3a) The IOAG will define in the SOP a simple pass procedure to allow an efficient coordination on the execution of the support;

3b) The IOAG will define in the SOP a simple procedure to quickly establish or acquire communication lines;

4a) The pass procedure will also address the pass termination exchanges, including the identification of the next contact times;

4b) The IOAG Members will initially use the standard outputs of their scheduling systems to reflect the future unallocated times.

Process 5 Near-term. Support Termination

The support termination process addresses the reporting and the accounting of the supports. Both are initiated by the Provider of the services.

The IOAG has identified the following tools to initially support the process:

1) The IOAG will define in the SOP a simple pass procedure to allow an efficient coordination on the execution of the support; this will indicate the elements to be reported post pass and/or at the termination of support.

2) The IOAG Provider Members will initially use the standard outputs of their scheduling or statistics systems to provide their accounting of the executed supports

2. Long-Term Approach

It is recommended that the IOAG Member agencies be prepared to implement and operate the standard service management functions as the CSSM standards become available. In many domains, these new standards will serve the purpose of replacing the interim solutions put in place for the short term in a more standardized and possibly automated way. Of course, not all the SOP procedures will be impacted as some will remain applicable, like the a priori licensing, the line establishment procedure or the pass procedure, among others.

In the following long-term processes, the new standards under development with the CCSDS are identified together with the tools they are expected to replace at that time.

Process 1 Long-term. Selection of a Provider

The Services Catalog standard is expected to enable a User of services to evaluate the suitability of a Provider of Cross Support Services, to provide the required supports, both at G/S and G/G levels.

Process 2 Long-term. Assessment on Ability to Support

The Service Agreement and Service Configuration profile standard is expected to enable a User of services to establish an agreement with a Provider of Cross Support Services Data for a specific phase of a mission, e.g.: the ECS. Such agreement may contain the configuration profiles for expressing the configuration of cross supported services and will define the data format for expressing the configuration of cross supported TLM, TRK, CMD services.

Process 3 Long-term. Support Preparation

The Utilization Request Format standard will define the data format to indicate requests for planning data, schedules, submission of trajectory data, submission of service configuration profiles, etc.

The Planning Data Format standard will allow indicating the communication geometry for a particular mission given a trajectory or return data volume estimates.

New Configuration profiles may also be used in the Service Period.

The Service Package Data Format standard is to enable a User of services to describe the services that are scheduled via committed packages of services. Such information may include real time Space Link services, retrieval services or offline services.

Process 4 Long-term. Pass Support

The Space Link Event Sequence Data Format standard will define events such as start/stop of return or a forward carrier, start/stop times of data transport availability, configuration changes with the space link or the transport to properly coordinate TLM, TRK, and CMD services.

It must be noted here that the CCSDS Simple Schedule Format being the first standard in the CSSM series, if implemented by the various agencies, will represent a long way toward more expeditious, interoperable SECS. That standard will both address the scheduled supports and the unallocated times.

Process 5 Long-term. Support Termination

The Service Accounting standard will enable a Provider of Cross Support Services to report on the volumes and the quality of the services provided to a User of such services. The Service Accounting is used after the provision of the services phase.

D. The IOAG Programmatic Guidelines on SECS

The IOAG community is focused on identifying the space and ground communication & navigation support capabilities needed by potential cooperative programs and projects and on identifying the space and ground mission operation systems & services needed by potential cooperative programs and projects to achieve their scientific objectives[1].

Spacecraft Emergency Cross Support (SECS) is indeed an activity that responds strongly to these objectives and the intrinsic nature of emergency cross support offers added values to the IOAG community. Short of a multi-agency agreement with any binding, controlling authority, a set of guidelines on programmatic matters concerning the SECS is crucial.

In that regard, the following programmatic guidelines for each member agency have been identified for SECS services provision:

1) Enlist its communication assets (e.g. ground stations) as potential SECS providers to missions of other member agencies.
2) Enlist missions requiring SECS and obtain acknowledgement from agencies that could provide potential SECS for enlisted missions.
3) Obtain RF license for use by a given station (per "*a priori licensing*" scheme) for potential provision of SECS to other member agencies, such that, in time of service invocation, the timely use of certain frequencies is legal, ITU-compliant, and fully permitted by the national/local licensing authority.
4) For promoting the common goals of international space exploration, endorse the principle of providing the requested emergency support at highest priority allowable.
5) For achieving expedited emergency support, as either the SECS user or provider agency, agree to execute the standard operations processes/procedures, as defined by the IOAG, for the SECS interfaces.
6) With full-faith understanding, the SECS user agency accepts the condition that the provider agency will not be held liable for any negative consequences that may occur to the spacecraft during the service provision.
7) With the understanding that the incurred SECS costs, due to either upfront engineering or service execution, are hardly a primary issue, except for some agencies, endorse the establishment of a simple, reasonable cost attribution mechanism.

VI. Conclusion

To further facilitate the IOAG member agencies in devising their respective plans for adopting the recommendations for the SECS, we offer the following path forward:

1) The IOAG member agencies will act on some of the readily affordable, executable recommendations for the potential SECS to some of the potential user missions, without waiting for the emplacement of the whole suite of capabilities.
2) The IOAG member agencies will proceed with the development of the specification for the standard operations procedures (SOP) concerning the SECS interfaces between the provider and user. Such a cookbook procedure specification will initially focus on the near-term process without being dependent on the future availability of the complete suite of the CCSDS Cross Support Service Management (CSSM) standards.
3) The IOAG will take a coordination role in the development of a few SECS-specific tools and capabilities as the aide to the SECS interfaces. Chief examples of these may be SANA registries for the pre-defined parameters of the SECS assets, mission profiles of potential user spacecraft, configuration profiles of potential user spacecraft, and the associated APPs operating on these common databases.
4) As the SECS process and interfaces are in use by real-live user missions, the IOAG will function as a monitoring organization to assess, evaluate, and continuously improve their efficiency and functionality.
5) The IOAG will bring the key decisions based on the accepted recommendations on SECS to the IOP forum for securing the acknowledgment and programmatic support at the highest management level of each member agency.

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References

Proceedings

[1]Calzolari, G.P., Costrell, J., Hell, W., Liebrecht, P., Pilgram, M., Soula, J.M., Walker, J., "The Interagency Operations Advisory Group (IOAG) - A decade of leadership in International Space Cooperation," SpaceOps 2012_id1275295.

[2]Liebrecht, P., Soula, J.M., Pilgram, M., Calzolari, G.P., " Results from the recent Interoperability Plenary-3, and the implication on future interoperability for global space communication and operations architectures", SpaceOps 2014_id1791917.

Reports, Theses, and Individual Papers

[3]"IOP-3 Communiqué," Interoperability Plenary, https://interoperabilityplenary.org, 2013.

"Work Plan 2016," IOAG.A.WP.2016.001, Interagency Operations Advisory Group, https://www.ioag.org, 2016.

[4]"2015 Annual Report," IOAG.A.A .2015.001, Interagency Operations Advisory Group, https://www.ioag.org, 2015.