INTRODUCTION TO STANDARDIZED SPACECRAFT ONBOARD INTERFACES

Joseph F. Smith
Jet Propulsion Laboratory, Pasadena, CA 91109

Chris Plummer
Cotectic Ltd, Overijse, Belgium

Patrick Plancke
European Space Agency ESTEC, Noordwijk, Netherlands

ABSTRACT

The Consultative Committee for Space Data Systems (CCSDS), an international organization of national space agencies, is branching out to provide new standards to enhanced reuse of onboard spacecraft equipment and software. These Spacecraft Onboard Interface (SOIF) standards will be based on the well-known Internet protocols. This paper will provide a description of the SOIF work by describing three orthogonal views: the Services View that describes data communications services, the Interoperability view shows how to exchange data and messages between different spacecraft elements, and the Protocol view, that describes the SOIF protocols and services. This paper will give the reader an excellent introduction to the work of the international SOIF team.

KEYWORDS

Standard spacecraft interfaces, Standard instrument interfaces, Spacecraft onboard interfaces, Spacecraft communications protocols, Spacecraft communications standards

INTRODUCTION

The CCSDS Work Area for Spacecraft Onboard Interface (SOIF) Services is setting out to develop recommendations for spacecraft onboard interfaces [1] [2]. We firmly believe that these recommendations will profoundly affect the development of both the flight hardware and software of future spacecraft. This paper discusses the SOIF activity, detailing its scope, objectives, and the progress made so far.

The Scope of SOIF: SOIF addresses the electrical and communications interfaces onboard the spacecraft, and encompasses the electrical, software, and protocol aspects of those interfaces. In order to limit the activity so that we can generate the first stable recommendations within two years, we are concentrating initially on the communication interfaces between flight units, which include the spacecraft onboard buses, and electrical interfaces to sensors, actuators devices, subsystems, and payload instruments. Our expectation is that, with recommendations on these aspects deployed, support for SOIF will grow and the activity will expand to address other areas, such as the more complex software aspects of these interfaces.

The results of the SOIF activity will be published in the form of CCSDS Blue Book recommendations containing the specifications for the interfaces. Since the scope of SOIF is so large, these recommendations will be published in several parts [3], and projects can elect to comply with one or more parts as appropriate. This allows us to promote a phased adoption of SOIF with some parts of the recommendation being available before others, to simplify project tailoring, and adapt to changes in the future.

Furthermore, there will also be a number of CCSDS Green Books developed, which will provide background and descriptive information. In order to fully understand the SOIF recommendations before implementation, it is best to first consult the Green Books, especially for the Concept and Rationale Green Book [1], and the other Green Books listed in that reference.

The Need for SOIF: Standardizing the onboard interfaces, and producing well-structured and comprehensive recommendations should lead to:

- "Plug and Play" for instruments, subsystems, components, devices, and sensors
- Reduced development costs and risks for onboard hardware and software
- Shorter development times for the spacecraft flight element,
- Shorter spacecraft flight element integration times,
- Shared design and test documentation for spacecraft onboard systems
- Increased potential for flight equipment re-use,
- Increased potential for flight software re-use,
- Increased potential for test equipment and procedure re-use,
- Potential for improved quality of flight and test equipment,
- Potential for development of standard components,
- Potential for second-sourcing of flight and test equipment,
- Better potential for secondary or "quick-ride" payload development,
- Easier adoption of new and evolving technologies in the future, including hardware and software upgrades, autonomy and vehicle health management.

It is clear from this list that SOIF impacts just about all areas of the development of the flight electronic systems, including both the electronics hardware and the software.

THE OBJECTIVES OF SOIF

The generation of internationally agreed recommendations and the realization of the benefits listed above are clearly the primary objectives of SOIF. However, there are three other objectives that must also be met.

The first of these objectives is to develop a set of SOIF communications services for the users that will meet the specific needs of spacecraft systems. These services (and the elements that support them) will need to meet the needs of the users without excessive overhead or excessive use of resources. This is certainly true of spacecraft, since mass, power, volume, and computational & communications resources onboard spacecraft are always limited.

The second of the SOIF objectives is to select a set of protocols to support the SOIF services that make sense in the spacecraft environment. These protocols will include the popular TCP/UDP/IP protocols (Transmission Control Protocol/User Datagram Protocol/Internet Protocol) [4], but perhaps with a selected set of RFC's (requests for comments). The Space Communications Protocol Standards (SCPS) [5] will also be an option.

The third of the SOIF objectives is to be able to change the underlying data bus to meet the specific needs of a particular spacecraft mission without affecting the implementation of the protocols or the SOIF communications services. In this way, it will be possible to change the underlying data bus without affecting the user applications. It will also be possible to use wireless communications media, and to use the SOIF communications services and protocols to provide seamless communications between nearby spacecraft, such as in constellations, formation flyers, and cooperating spacecraft.

A byproduct of these objectives is that the SOIF standards will enable a "Plug and Play" capability, specifically for space and earth science instruments. SOIF compliant science instruments will be able to move from one SOIF compliant spacecraft to another, even if there is a different data bus implemented on the new spacecraft. This movement of instruments should be possible with only a change in the actual data bus interface card, and the software drivers for that data bus.

Finally, SOIF must be compatible with other, existing standards that are used onboard spacecraft, such as the CCSDS Telemetry and Telecommand standards [6] [7], and the ESA Packet Utilization Standard (PUS) [8].

THREE VIEWS OF SOIF

The preceding sections have painted a rosy picture of the SOIF objectives, but making SOIF a reality, i.e. taking these objectives and turning them into a set of recommendations that can be understood and used in spacecraft projects, requires a well-chosen, pragmatic approach.

One of the main problems is that, because of its broad scope, SOIF is seen as many different things by many different people. For example, spacecraft onboard hardware developers are expecting to see detailed electrical specifications for onboard interfaces. Onboard software developers are looking for abstract interfaces that make it easier for them to access common services for data transfers, device data acquisition and commanding. Spacecraft system engineers are looking for recommendations that will increase the ability to interoperate and to re-use flight components across different platforms. The space instrument (payload) developers are looking for the "Plug and Play" capability that will allow them to move their instrument/payload to another mission with a minimal effort. And project managers are looking for solutions that will save them schedule time and money on their projects, and reduce cost and schedule risks.

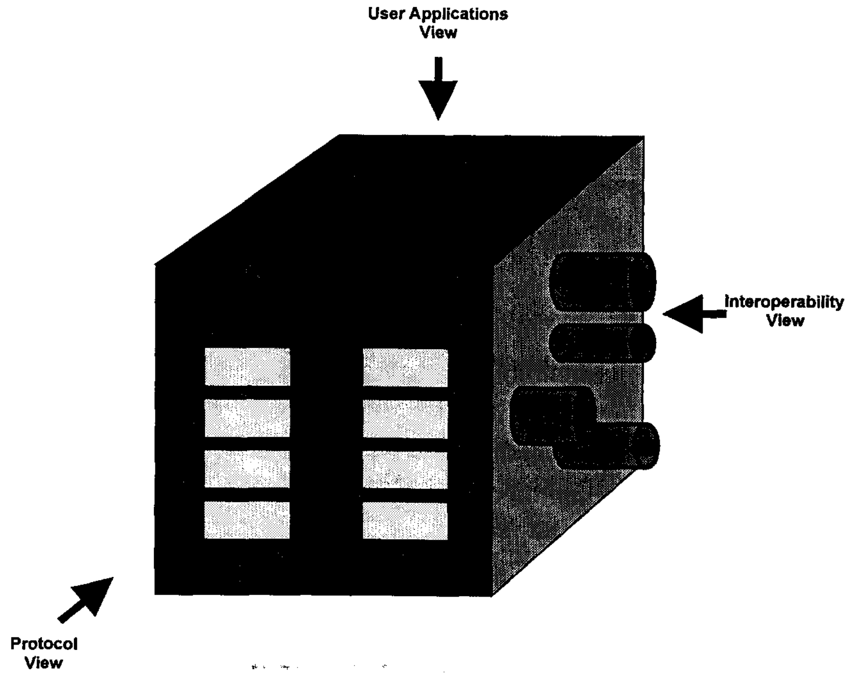


Figure 1 - Three Orthogonal Views of SOIF

All of these views, and many others, must be taken into account in the preparation of the SOIF recommendations, and we are putting a great deal of effort into making the recommendation easily understood by these different communities. The solution that we have adopted is a careful structuring of the recommendation document tree [3].

Another problem that we face, again due to the broad scope of SOIF, is that within this work area we have people with a broad range of skills and specializations. Many of these specializations have their own distinct way of looking at problems, and their own vocabulary for describing things. In order to get the most out of the individual participants in the SOIF work area, we have divided the tasks up into key areas, each of which is addressed by a Working Group or Birds of a Feather group. This new organization within CCSDS (introduced in April of 2003) is similar to the previous SOIF sub-panel organization, and has reduced the need for the Work Area members to become distracted by issues that they are not interested in, and has allowed work on the key areas to be carried out much more efficiently and in parallel with other activities.

The recognition of several views of the SOIF problem domain has been an important step in our standardization activities. Figure 1 shows three orthogonal views of the SOIF problem domain, and discussion of each of these views can give some insight into how the SOIF work area is attempting to accommodate them.

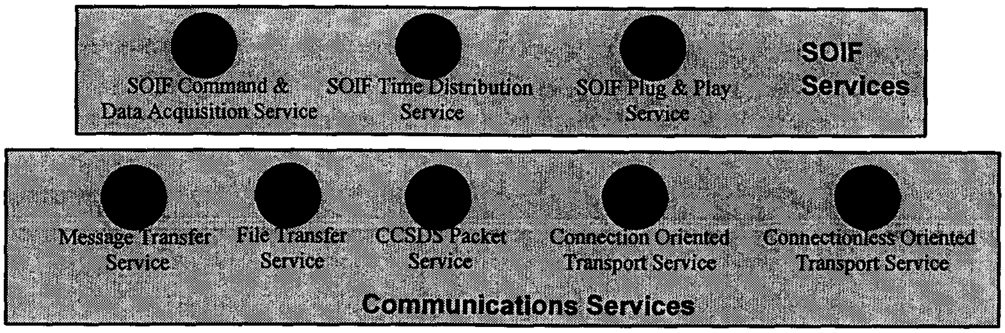


Figure 2 - User Applications View of SOIF Services

The User Applications View: The first view to consider is the user applications view. This is the view of software engineers and programmers developing flight applications for a spacecraft. Since these are one of the most important 'customers' for SOIF, we need to fully understand their view. Typically, application developers see a set of application programming interfaces (APIs), i.e. a set of procedure and function calls, which are shown in Figure 2, that they can bind with their applications to access the services offered by SOIF [9].

From the user application view, not only is the underlying hierarchy not visible, but also is not of interest. Users see only a set of APIs that are uniformly accessible from each application. These APIs correspond to the service access points exposed by the SOIF stack.

The Interoperability View: The second of the three views of SOIF is interoperability. Interoperability is the ability of a device or application to operate with another device or application, where the two devices or applications are both SOIF compliant. This would mean that it would be possible for two spacecraft application to locate and communicate with each other if they are both using SOIF compliant protocols (including Data Link and Physical Layers). This communications between devices would be possible as long as: both of the devices shared a common understanding of the SOIF protocol that flows between the devices, both devices shared a common definition of the functionality that is implemented in each SOIF layer, and both devices used a common PDU to communicate between the two SOIF layers.

This concept of SOIF interoperability is shown in Figure 3. This diagram shows how the only physical connection between these two devices will be the physical media between them. The bits of that flow on the physical media between the devices are used to move the encapsulated PDUs from each of the different layers. But across the physical interface, we not only have the indirect physical flow of these encapsulated PDUs, but also an implied direct connection of the protocols between the two different implementations of each layer. So each layer in a device uses the PDU for that layer to transfer the information necessary for the two instantiations of the layer to operate in concert with each other, providing the agreed functionality to move the information from one user to another.

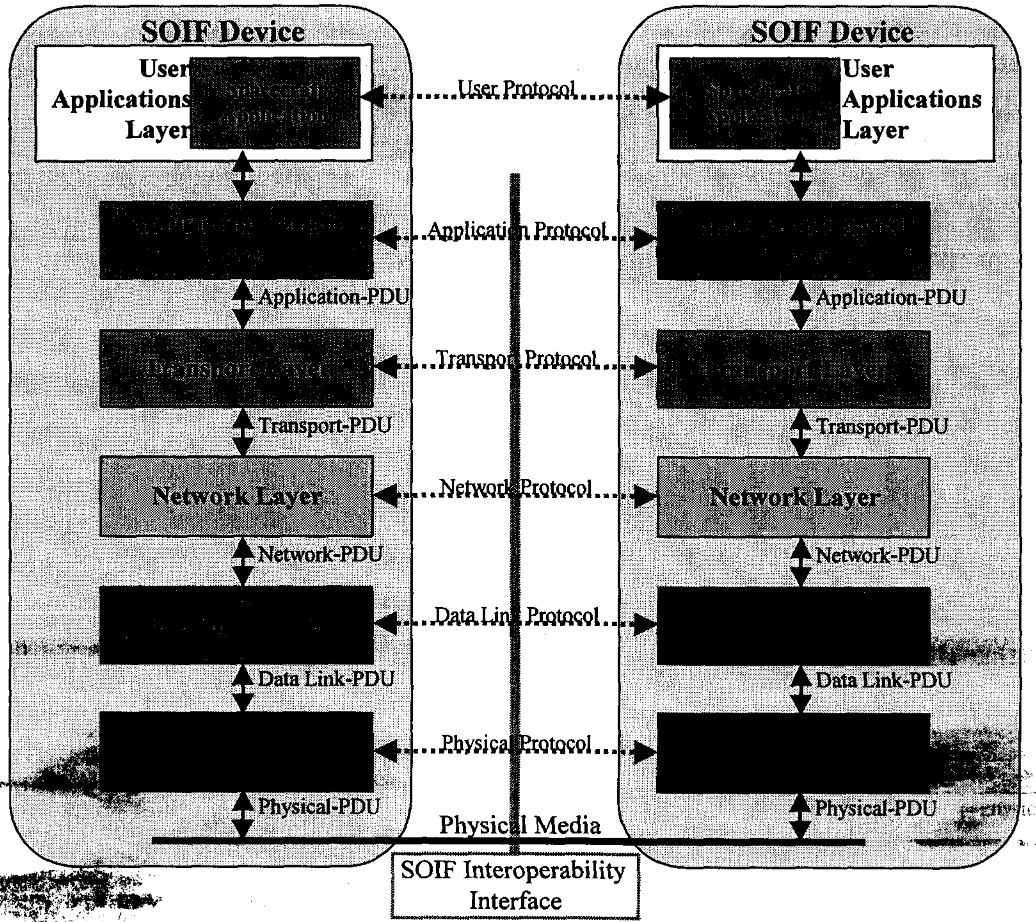


Figure 3 – Interoperability View of SOIF

Implied in all of this, it is also necessary for the two spacecraft applications (or two instantiations of one application) to be able to communicate with each other, by having a shared understanding the contents of the User PDU that flows between them, and by using the same functionality and protocol. This will be necessary; otherwise SOIF would accurately deliver messages between the spacecraft applications that could not be interpreted.

The Protocol View: The last view can be called the protocol view, and is shown in more detail in Figure 4. This sees the SOIF problem as being similar to that addressed by classical communication architectures like the ISO (International Organization for Standardization) OSI (Open Systems Interconnection) 7-layer reference model [10], or the Internet protocol stack. Under this view, the solution to the problem is seen as a set of hierarchically ordered services. The key to meeting the SOIF goals of being able to tailor and scale the solution for different situations, and to allow evolution and development in the future, is in the relationships between the services, which are determined by the definition of the service interfaces.

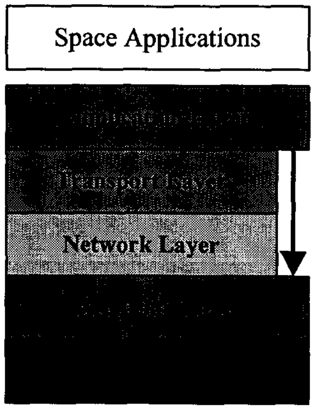


Figure 4 – Protocol View of SOIF

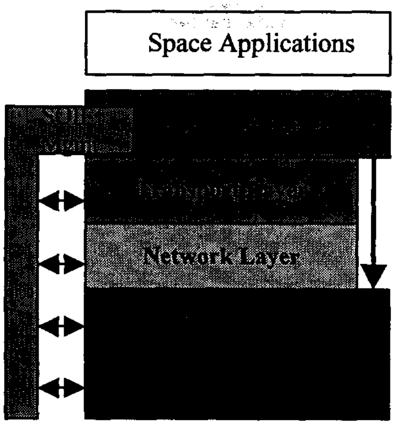
This view is natural to many of the sub-panel members, particularly those who have been involved in protocol design and communication system engineering in the past. It is quite likely that the protocol view will be that seen by the implementers of SOIF, i.e. the engineers responsible for providing SOIF services on a given spacecraft. However, this view is not intuitive to many of the potential users of SOIF, particularly software application developers who write the flight application software, and hardware designers who make hardware interface components.

THE SOIF ARCHITECTURAL MODEL

The SOIF architectural reference model is layered according to the principles of the ISO OSI Reference Model, and is depicted in Figure 5.

The SOIF reference model layers differ from the actual layers named in the OSI reference model because we have chosen not to include Presentation and Session layers. The correspondence between the SOIF layers and the OSI layers is shown in Figure 6.

The SOIF ***space application layer*** contains user-oriented services that are presented to SOIF users that reside outside of the model. Typically a SOIF user is an onboard application that makes use of the SOIF services to access other onboard applications, and onboard hardware devices (sensors and effectors). This layer does not have an equivalent layer in the ISO 7-layer model, but would be equivalent to a possible eight layer.



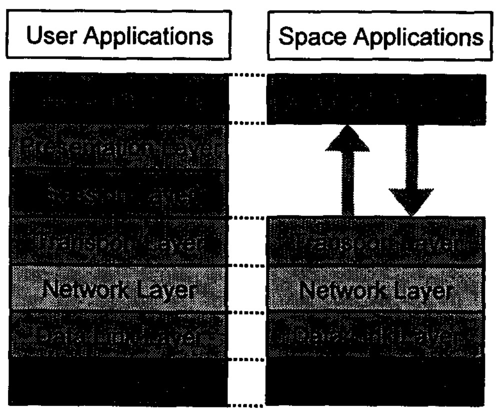


Figure 5 – Simplified SOIF Reference Model

Figure 6 – Comparison of SOIF and ISO Reference Models

The SOIF ***applications layer*** provides the fault tolerant message capability that is required by the SOIF services in the *space application layer*. This layer also provides the fault tolerant file transfer capability that can be used by the SOIF services or the applications. And the *applications layer* will also have a CCSDS packet service that can be used to move these packets as required. The SOIF application layer is equivalent to the application layer of the OSI 7-layer model.

The SOIF ***transport layer*** contains services that enable end-to-end transfer of messages between users. The SOIF transport layer is the equivalent of the transport layer of the OSI 7-layer model.

The SOIF ***network layer*** contains services that control the operation of the underlying sub-networks and enable data to be routed throughout the spacecraft network. This layer would also allow data to be routed to where ever it would need to be move. This layer corresponds directly with the network layer of the OSI 7-layer model.

The SOIF ***data link and physical layers*** contains services that implement the onboard sub-network and interfaces to other onboard devices, subsystems, and instruments. Typically, onboard sub-networks comprise onboard buses as well as point-to-point links between flight units. The SOIF data link and physical layers corresponds to the data link layer and the physical layer of the OSI 7-layer model.

The SOIF ***management service*** provides the capability of managing the SOIF stack. Because this service is accessed as a user application, and controls the configuration of each layer, it is represented as another user application connected to a vertical slice spanning all of the layers of the reference model in accordance with accepted OSI convention.

CONCLUSIONS

SOIF is a very active, international initiative by the CCSDS and fully supported its sponsoring agencies and industry to define standards for spacecraft onboard interfaces. This work has a very broad scope, and is likely to have a beneficial effect on many aspects of spacecraft onboard systems in the future. Within the space of this short paper we have only been able to give a brief introduction to SOIF and its progress so far.

We apologize to many of our SOIF colleagues for not having featured some of their activities, particularly relating to the SOIF messaging service and network management aspects. This has been due only to a shortage of space. These and other aspects of the SOIF work will be published in the future.

ACKNOWLEDGEMENT

SOIF is a collaborative activity involving many individuals from different countries and organizations throughout the world. We gratefully acknowledge all of the contributions of the SOIF work area members during the twice-yearly face-to-face meetings, and the numerous teleconferences and e-mail exchanges that have brought us so far.

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ACRONYM LIST

API:	Applications Programming Interface
C&DA:	Command and Data Acquisition
CCSDS:	Consultative Committee for Space Data Systems

ESA:	European Space Agency
IP:	Internet Protocol
ISO:	International Organization for Standardization
OSI:	Open Systems Interconnection
PDU:	Protocol Data Unit
PUS:	Packet Utilization Standard
RFC:	Requests for Comments
SCPS:	Space Communications Protocol Standards
SIG:	Special Interest Group
SOIF:	Spacecraft Onboard Interface
TCP:	Transmission Control Protocol
UDP:	User Datagram Protocol