STANDARD USER DATA SERVICES FOR SPACECRAFT APPLICATIONS

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ABSTRACT
The Consultative Committee for Space Data Systems (CCSDS) is an international organization of national space agencies that is branching out to provide new standards to enhanced reuse of spacecraft equipment and software. These Spacecraft Onboard Interface (SOIF) standards will be directed towards a spacecraft architecture, as a distributed system of processors and busses. This paper will review the services that are being proposed for SOIF. These services include a Command and Data Acquisition Service, a Time Distribution Service, a Message Transfer Service, a File Transfer Service, and a CCSDS Packet Service. An Instrument & Subsystem “Plug & Play Service is currently under study, but is included in this paper for completeness.

KEYWORDS
Standard spacecraft interfaces, Standard data services, Standard communications services, Spacecraft user services, Standard user services, Spacecraft plug and play

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 flight hardware and software of future spacecraft. This paper will expand on a SOIF overview paper [3], by providing a description of the SOIF user services. These are the services that the users can and will expect to use to access the advantages of SOIF.
THE SOIF REFERENCE MODEL

The SOIF Services Working Area has developed a SOIF Reference Model. Within the SOIF Working Area, we are using this model to describe and document our work, both for ourselves, and to others.

Figure 1 shows the SOIF Reference Model [1]. This figure shows how the SOIF layers relate to each other, and where the SOIF communications services fit within these layers. The access points for these SOIF services are shown in this figure as the ellipses [3].

Figure 1: The SOIF Reference Model

THE SOIF SERVICES

We are going to be introducing these services by the layer in the protocol stack, as shown in Figure 1. The services are located in the Transport Layer, the Applications Layer and in the Space Applications Layer. There are seven (7) SOIF services that are presently defined and will be available to the users.
SOIF TRANSPORT LAYER SERVICES

The users will have the ability to directly access the Transport Layer. The services being considered at the Transport Layer will be a reliable (acknowledged) and unreliable (unacknowledged) transport service. In the Internet protocols, these services could be provided by the well known TCP/UDP protocols. The designer may also wish to use an alternate protocol, such as the Space Communications Protocol Standards (SCPS) [4], which has been optimized for the space-ground communications link, when the spacecraft is in a near-earth orbit.

The Transport Layer interfaces will not always be available because not all implementations will require the use of the Transport and Network Layers. For example, if a spacecraft has only a single subnetwork, then the functionality of these two layers may not be required or implemented. Therefore these implementations do not have these Transport Layer Services available, and it is not possible to use these services as a generic interface.

SOIF APPLICATIONS LAYER SERVICES

As we can see in Figure 1, there are three more data services in the Applications Layer.

Each of these Applications Layer services will provide the same standard interface to all of its users, and can then use all the services provided by the protocol. Otherwise the user will either need to supply the service itself (e.g. reliability, routing, multi-link transparent transport), or do without the service. However, for most applications the use of these higher-level interfaces will provide significant benefits in terms of portability, functionality, and isolation from changes at the lower layers.

Because of this, the Applications Layer services will isolate the details of the underlying data bus from the users. In a later section of this paper we will show how these services in the Applications Layer will provide this isolation.

The Message Transfer Service [5] is used to move arbitrary-sized discrete messages between software processes (users) within the spacecraft, where the user can define the Quality of Service provided by the service (e.g., guaranteed or non-guaranteed delivery). The interface supports both peer to peer and client server interaction models, and provides primitives that can be used to construct basic publish / subscribe interaction pattern if such is desired. The basic elements of this include: name and address resolution, connection establishment, synchronous and asynchronous message transfer mechanisms, and synchronization mechanisms for cooperating processes. Mechanisms are also provided to enable discovery of available Quality of Service (QoS), to select QoS, and for error reporting and service monitoring suitable for operation in a space environment.

The File Transfer Service is used to move files between users onboard or within the vicinity of the spacecraft. This data structure would be preferred in a number of cases, such as a complete set of related scientific observations (telemetry), a set of commands to a particular destination, or a patch or update to the flight software for a particular instrument or subsystem.
The **CCSDS Packet Service** is the final of the three services, and is specifically used to move CCSDS Packets around the spacecraft at the Applications Layer, as required by the users. This format is particularly useful because some Space Applications Layer services are specifically designed to operate with data in this format. The European Packet Utilization Standard (PUS) [6] is perhaps the most popular of these Space Applications Layer users, even to the point that a standard for this service has been created for use by the European Space Agency.

**SOIF SPACE APPLICATION LAYER SERVICES**

And in Figure 1, we can also see that there are three other SOIF services in the highest of the layers, the Space Applications Layer. The Space Applications Layer services use the Applications Layer services to move data around the spacecraft.

*The Command and Data Acquisition Service* (C&DA) is used to provide low overhead access to read data from spacecraft sensors and to also provide low overhead commands to spacecraft actuators. A central aspect of this service is that it will be able to provide access to any sensor or actuator, no matter where on the spacecraft (relative to the user) that the sensors or actuators are located.

There are six capability sets that make up the functionality of the C&DA service, and they are as follows:

- **Device Access:** where a user-supplied logical address of the device is converted by the service into a network address, allowing the device to be accessed from anywhere in the network.

- **Engineering Unit Conversion:** which will convert the binary value obtained from reading the device into the engineering units of the measurement. In other words, by using this capability, the user will be reading a temperature, voltage, or pressure, instead of receiving a raw number in which the user must make this conversion.

- **Data Product Acquisition:** where data from multiple sensors can be read from a single access, and simple calculations can be made from these multiple readings.

- **Data Monitoring:** the requested data is monitored against declared limits (for example red-line and yellow-line limits) and only reported to the user when the data goes outside the limits.

- **Device Virtualization:** devices are read and controlled using a virtual generic device image, or model. Models can also be used to control more complex devices, such as a reaction wheel.

- **Data Pooling:** where the Data Pooling function performs a periodic read of the sensor data, and places the most recent into a data pool (data base). The user can access the periodic data from the sensor data pool or database, and will access the most recent data.

*The Time Distribution Service* allows users to obtain a time value that is correlated with the centrally maintained spacecraft onboard time. This service is also used for distribution of time from
a central spacecraft clock to any distributed clocks that may be located in different elements of the spacecraft avionics. However, the methods that are used to keep the central spacecraft time synchronized to the ground or control center are beyond the scope of this SOIF Time Distribution Service.

**The Plug and Play Service** is the newest addition to the SOIF Reference Model. Indeed, the Plug and Play Service is so new that this discussion is still somewhat speculative. However, much of our user feedback has requested this type of service, so it will be included herein.

It is intended that the Plug and Play service provide a capability to allow software components, complex instruments, and subsystems to be dynamically inserted into the spacecraft while it is operating. This will allow, for example, software upgrades to take place in a running system, a new instrument to be inserted during spacecraft integration, or a spare instrument to be powered up and brought into operation during the course of a mission.

**ACCESS TO THE DATA LINK LAYER**

Figure 1 showed the SOIF Reference Model, and we have briefly mentioned how the services in the SOIF Application Layer can be used to isolate the user applications from the underlying data bus. This section describes in more detail the alternate implementation approaches that may be taken.

For this discussion, we will assume that all users from the Space Applications Layer will access the lower layer communications by way of one of the three Application Layer services: the Message Transfer, File Transfer, or CCSDS Packets services.

Figure 2 illustrates two alternate protocol paths down the stack that the service implementation may take to the Data Link Layer. The path of the arrow on the right shows the case when there is only one subnetwork (data bus) onboard the spacecraft. This means that there is not only one type of subnetwork, but there is only one physical subnetwork on the spacecraft.

The arrow on the left in Figure 2 shows the other case, when there are multiple subnetworks available to the spacecraft. In this case, it will be necessary to implement the Transport and Network Layers, in order to provide the functionality of these layers across the multiple subnetworks. In this case, there can be several subnetworks on the spacecraft, and they can even be of different types. It is even possible that a spacelink subnet (RF) can be used to connect two different spacecraft, if they are close enough for the Transport and Network Layer protocols to still work.

In either case, the services in the Space Application and Applications Layers isolate their user from which protocol path through the stack is used for a particular implementation/deployment.

The implication of this discussion is that SOIF will be able to deliver on its promise for interoperability. With all of the users (be they subsystems, instruments, or hardware devices) using the SOIF Space Applications and Applications Layer Services, the users can be interchanged at will. Similarly, it will be possible to change out the underlying data bus without any effect on the users. Or, it will be possible to move a user from one spacecraft (for example if it has only one data bus) to
another spacecraft, (even if it has multiple data busses, and none of them use the same data bus technology as the first spacecraft) without effecting the user implementation.

![Diagram of communication layers and services](image)

**FIGURE 2: TWO PATHS TO ACCESS THE DATA LINK LAYER**

Of course, the effect on the overall system must still be accounted for, e.g. an increase in bus utilization. However, through the use of such standard services, it should be simpler to characterize these parameters, and hence determine the resulting performance of a system being designed from re-used user components and SOIF services.

**CONCLUSIONS**

Ultimately, this flexibility of SOIF to operate in any number of different interoperability scenarios will be very important in the ultimate acceptance of SOIF in the larger spacecraft community. As these capabilities are diffused throughout the industry, we can expect that SOIF will start to bring increased levels of cost savings and reduced risk to a large number of different missions. Indeed, we in the SOIF Work Area believe that once SOIF is well known and understood, these
recommendations and their successors will be the dominant spacecraft interface technology for the next few decades.

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REFERENCES

[1] Spacecraft Onboard Interfaces – Concept and Rationale, Consultative Committee for Space Data Systems, Green Book CCSDS 830.0-G-0.4, 2002


ACRONYM LIST

C&DA: Command and Data Acquisition
CCSDS: Consultative Committee for Space Data Systems
FDIR: Fault Detection, Isolation, and Recovery
PUS: Packet Utilization Standard
RF: Radio Frequency
QoS: Quality of Service
SCPS: Space Communications Protocol Standards
SOIF: Spacecraft Onboard Interface
TCP: Transmission Control Protocol
UDP: User Datagram Protocol