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Transitioning from Space Shuttle to Space Station On-Orbit Servicing

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ABSTRACT

On-orbit satellite servicing has been demonstrated on a variety of missions using the Space Shuttle. This capability is also a stated goal of the Space Station and other unmanned vehicles. Serviceable spacecraft should be able to take advantage of all these servicing facilities. This paper will discuss one effort to document currently available or nearly operational servicing interfaces. Availability of this type of compiled information will assist in a smooth transition from Shuttle-based satellite servicing to servicing at a wider range of locations and by different servicing vehicles.

INTRODUCTION

The on-orbit servicing of spacecraft is a capability which has long been envisioned and is now reaching an operational status through the use of the Space Shuttle and the Space Station. A number of missions in the recent past have served to illustrate the advantage of this capability. The repair of the Solar Maximum Mission (SMM) spacecraft and LEASAT, the recovery of Westar and Palapa, and various other experiments conducted by NASA have demonstrated both IVA and EVA capabilities in this area. NASA has also shown a commitment to on-orbit servicing by requiring the Hubble Space Telescope (HST), the Gamma Ray Observatory (GRO), the Explorer Platform, and other future spacecraft to use this capability. Designing future vehicles to use the capabilities developed for the missions mentioned above is fairly straightforward. However, designers involved with Space Station and remote servicers as well as spacecraft manufacturers (the servicees) are faced with the dilemma of anticipating the other's needs and capabilities. This typically results in an unwillingness on both sides of the servicing operation to proceed without first obtaining detailed information from the other side. This paper will focus on the standard interface as the means of allowing both the servicer and the spacecraft requiring servicing to design their respective systems with the knowledge that the other partner in the servicing process will be compatible. Design engineers are thus free to optimize their vehicles based on other requirements while retaining the ability to be serviced, so long as the interface is maintained.

CURRENT AND FUTURE CAPABILITIES

As mentioned above, a number of services are currently available from the Shuttle. These services, as depicted in Figure 1, include:

- Experiments and concept demonstrations on the Orbiter middeck
- Retrieval and return to Earth of defective spacecraft for refurbishment as exhibited by the Wester/Palapa recovery
- Routine/scheduled on-orbit servicing such as that anticipated for the HST
- Unscheduled on-orbit repair as carried out for the SMM vehicle
- Replenishment of consumables as demonstrated by the orbital refueling system and as anticipated for GRO
- Deployment/retrieval of large modules which may be used to supply on-orbit manufacturing facilities with raw materials or return finished products

These capabilities and missions indicate the beginning of standard interface use by the aerospace community (e.g., the three-point docking adapter used by SMM, GRO, and HST, the standard RMS grapple fixture, etc.). They also indicate where the addition of a standard interface (namely, a grapple fixture on Westar and Palapa) would have greatly simplified the servicing mission.

With the exception of Earth return, the Space Station and the Orbital Maneuvering Vehicle (OMV) will offer a similar if not expanded range of on-orbit satellite servicing capabilities. The Space Station will have the added advantages of providing extended servicing time on orbit (should unexpected problems occur during the servicing operation), as well as a temporary storage location for spacecraft and servicing supplies. The OMV will initially act as a deployment/retrieval vehicle but will later evolve into a remote servicer. Servicing offered by both of these vehicles will evolve and grow as experience in and understanding of servicing operations increase.

However, as the number of serviceable satellites grows, the range of servicing requirements will also grow and evolve in ways only partially understood or not yet conceived. In addition, the lead time required for new spacecraft is placing designers in the position of conducting trade studies for vehicles which could use the Shuttle, Space Station, or a remote servicing capability. To conduct these trade studies, designers must know what hardware is available, what interfaces will be used, and what it will cost to carry out servicing operations. Some of this information is available now from NASA and various contractors, although in most cases it must be assembled from a wide range of sources. The remaining information does not yet exist, since there has been no current or near-term operational requirement, and, therefore, assembling or creating the required data has been deferred. Vehicle designers who will be operating in the Space Station era are thus faced with a number of dilemmas. They must first decide whether or not to make their vehicle serviceable, given an uncertain knowledge of the operating environment and hardware capabilities. If this decision is affirmative then they must determine if the vehicle must be tailored to the unique requirements of a specific servicer. This may force a reliance on that one servicing location for all activities of this type and may result in delays when the servicer is unavailable. This is not a desirable situation for servicing in general or, in particular, for the transition period now being entered when the Space Shuttle, Space Station, and other vehicles will all have servicing capabilities.

STANDARDIZED INTERFACES

Known, standardized interfaces will be essential to allow a smooth transition from Space Shuttle-era servicing to Space Station-era servicing, while continuing to allow for the use of the Shuttle if necessary. The spacecraft operator should not be forced to decide, at an early point in the spacecraft development, where the servicing will take place, due to interface restrictions or unique designs. Nor should the servicer be forced to accommodate a multitude of unique spacecraft requirements. Standardized interfaces will alleviate many of these problems by making design details on either side of the interface independent of the opposite side. The designer is thus allowed to optimize the spacecraft for its particular mission needs while still taking full advantage of the services offered at a variety of locations. This also reduces the possibility of a single choke point should a particular servicing location become inoperative or otherwise unavailable.

Many examples of standardized interfaces exist in daily life, as illustrated in Figures 2 and 3. The ability to fill one's automobile with gasoline does not depend on which service station one enters. Nor does it depend on the type of car one is driving. Similar statements can be made for a wide range of pneumatic tires and common household appliances. These examples illustrate that standard interfaces are not only commonplace, but quite convenient and taken for granted once they are in existence.

It is not difficult to extrapolate this concept to satellite servicing operations, as Figure 4 illustrates. The RMS end effector and its grapple fixture, the refueling coupling developed for GRO, and the MMS/FSS berthing interface are all examples of servicing interfaces currently available and assumed to be de facto standards by a wide range of users. For this reason, both the servicer and servicee can design future vehicles to accommodate these interfaces. This practice has already proved its worth in an operational situation. The SMM repair mission was salvaged because the bus carried a standard grapple fixture even though the spacecraft was launched more than a year before the Space Shuttle completed its first flight. Applying this same philosophy to future designs will allow a wider range of vehicles to be serviced at a wider range of facilities even as both are being developed.

However, the current procedure for developing servicing interfaces may be described as ad hoc at best. Typically, the first version of a particular interface which is designed and built becomes the standard with little or no consideration of wider applications. This does not mean that, once developed, an interface could not be applied to different situations, but spacecraft and subsystem designers usually cannot take the time to make an exhaustive search of all possible sources of conceptual or flight-qualified interfaces. A consolidated source of information of this type will help accelerate the design process for serviceable spacecraft by reducing the effort spent on interface development.

SATELLITE SERVICES SYSTEM WORKING GROUP

A Satellite Services System Working Group has been established at Johnson Space Center to address this and other concerns related to Space Shuttle servicing operations. One goal of this group is to establish a handbook of currently available and proposed interfaces related to satellite servicing which will be made available to spacecraft designers. Details for each of these interfaces will be documented with the information contained on both sides of a single page in this reference document. The format to be used to present this information is illustrated in Figures 5 and 6. The first page begins with a photograph of the hardware item, followed by a brief description of the item and its potential uses. More details of the item's key features, how it performs its function, and a description of significant interface details is then provided. The first page concludes with the item's stage of development and a list of contacts for further details. The second page lists physical characteristics of the hardware item, including dimensional data, weight, power, type of material, and environmental limits. Also provided is information regarding the item's interface capabilities, such as minimum and/or maximum fluid flow rate, electrical current capacity, attachment bolt size and pattern, etc. Taken as a whole, the format provides the designer with sufficient data to decide if the interface is suitable for the design application plus points of contact for further information.

Guidelines for applying this information can be obtained from several sources if required. One example is the "Satellite Servicing Handbook - Interface Guidelines" (LSMC/-D931647) which was developed under contract to NASA/JSC (NAS9-15800), based primarily on lessons learned from the HST program. This handbook is still one of the best sources for this type of information. In addition, a Design Handbook for serviceable spacecraft is being prepared as part of the USAF Satellite Assembly, Maintenance and Servicing (SAMS) Study and will be available in the near future.

SUMMARY

If the same interfaces developed and used by the Space Shuttle are accommodated as part of the Space Station and OMV servicing operations, they will provide added incentive to the user community to take full advantage, at an earlier time, of serviceable options in future spacecraft designs. This will also provide an ample source of "customers" for all servicing locations: Space Shuttle, Space Station, OMV, and others. This paper has discussed one effort to document those interfaces currently available and those nearing operational status. Related efforts by other NASA centers, the USAF through its SAMS Study and Arinc standardization contract, will all contribute to this important effort by making practical, usable information available to the user community. Both the servicer and servicee will be the ultimate beneficiaries of the application of this information by making on-orbit satellite servicing a commonplace, "taken for granted" operation.

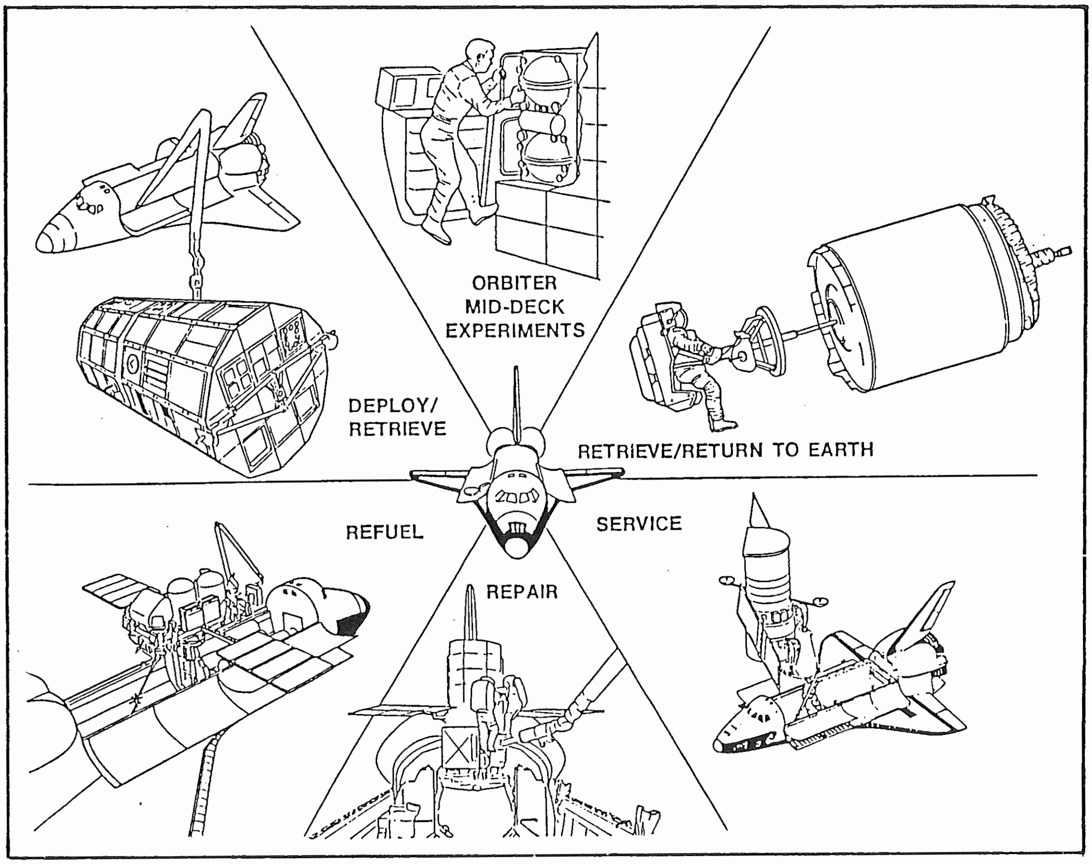


Figure 1. SHUTTLE SATELLITE SERVICING CAPABILITIES

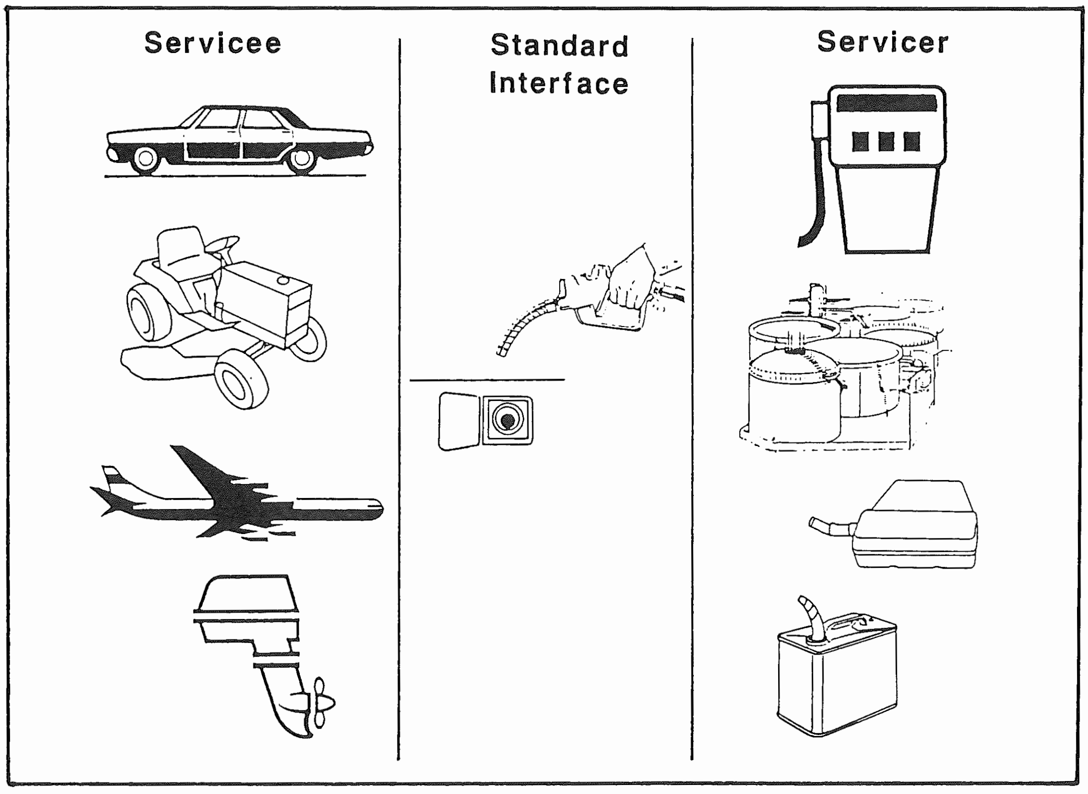


Figure 2. STANDARD INTERFACE FOR GASOLINE

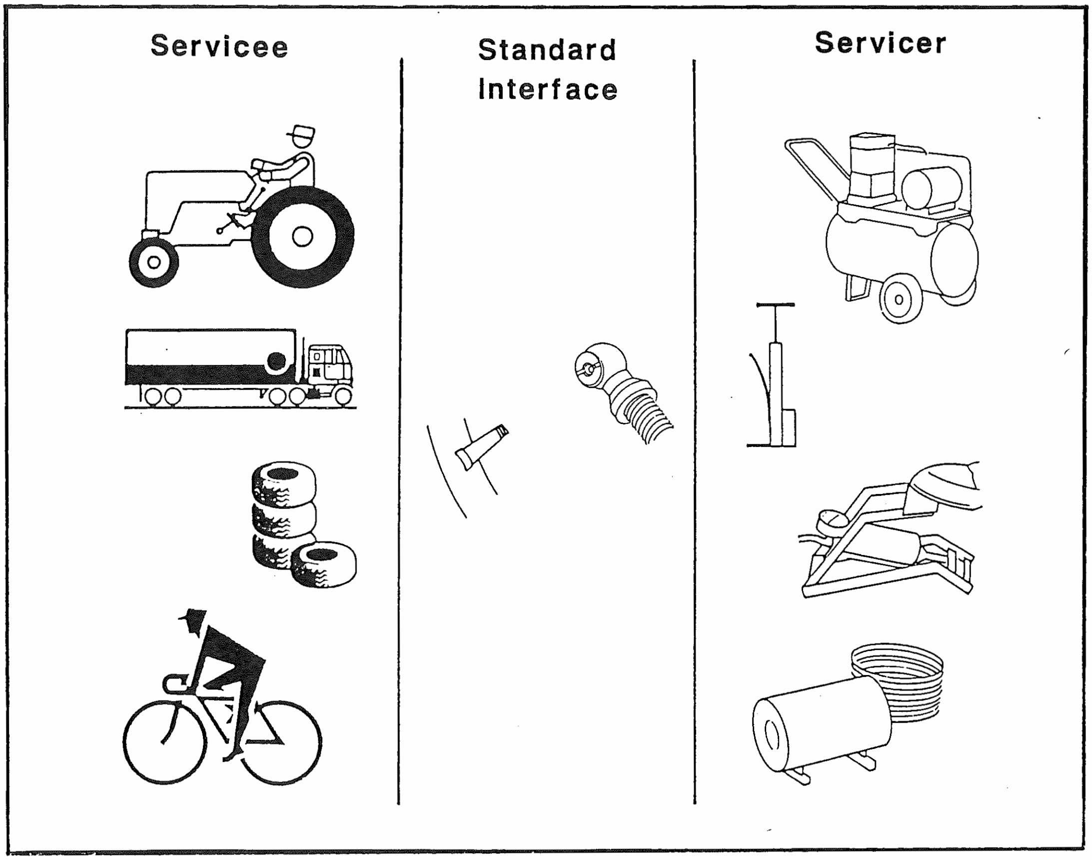


Figure 3. STANDARD INTERFACE FOR AIR

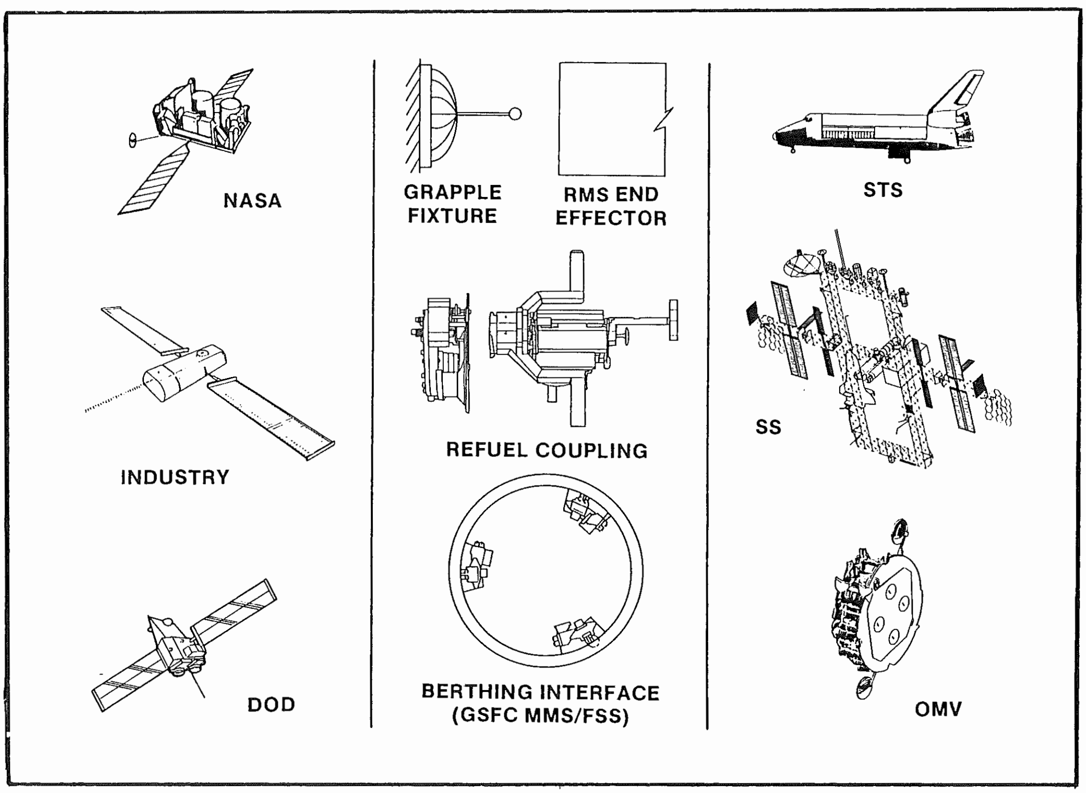
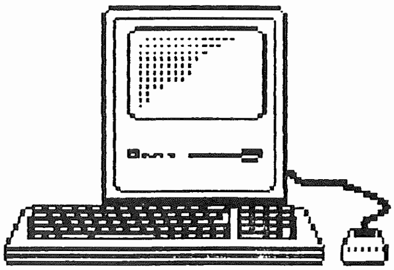


Figure 4. STANDARD INTERFACE FOR SPACECRAFT

EQUIPMENT NAME

S7464-44



OVERVIEW

A BRIEF DESCRIPTION OF THE ITEM AND ITS USES

OPERATIONAL COMMENTS AND INTERFACE PROVISIONS

A DESCRIPTION OF THE ITEM'S FEATURES, HOW IT PERFORMS ITS FUNCTION, AND SIGNIFICANT INTERFACE DETAILS

STATUS

THE ITEM'S STAGE OF DEVELOPMENT (PRELIMINARY DESIGN, FLIGHT READY, ETC.)

CONTACTS

SOURCE:
OPERATIONAL:

Figure 5. INTERFACE DOCUMENT REFERENCE PAGE: GENERAL CHARACTERISTICS

EQUIPMENT NAME

TECHNICAL INFORMATION	
PART NUMBER	12312313-324
WEIGHT	3455.24 LB
POWER	400 CYCLE AC; 110 V
STATUS	PHASE B HARDWARE
MATERIAL	STRUCTURE - 7075-T7351 ALUMINUM
TEMPERATURE RANGE	-30 TO 250 F

DIMENSIONAL DATA	
A	132.333 IN.
B	23.44 IN.
C	123.32 IN
D	9.87 IN.

INTERFACE DETAILS	
ELECTRICAL	
MECHANICAL	
FLUID	
ELECTRONICS	

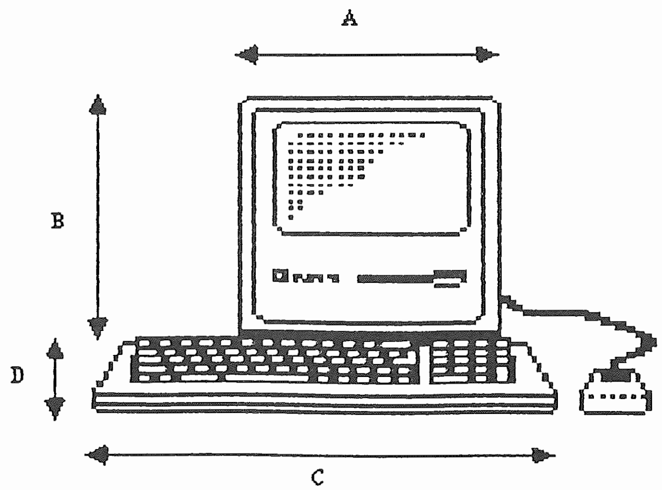


Figure 6. INTERFACE DOCUMENT REFERENCE PAGE: DETAILED SPECIFICATIONS