Primer on Operating & Support (O&S) Costs for Space Systems

by

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DISCUSSION PAPER

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INTRODUCTION:

As the Air Force expands its activities in space, we in the cost community are being increasingly requested to develop Operating and Support (O&S) costs for space based systems. Currently, the most common space system is the satellite with its associated ground-based support facilities. However, other systems are currently being developed such as the Strategic Defense Initiative (SDI), Space Station, space based radar, anti-satellite weapon, and others. Our difficulty in the cost community is in developing O&S cost estimates for all these systems.

As a result of this increased emphasis on O&S costs for space systems, we at HQ Space Command/ACM ~~are~~ is in the process of developing a primer on O&S costs for Space Systems. It is intended to provide some guidelines and fundamentals for estimating the O&S cost for space systems; to address the O&S costs associated with space systems; and to present methodologies and factors to estimate these O&S costs. ~~Additionally~~ An O&S cost element structure will be developed for space systems. ~~Hopefully~~ The primer will result in providing cost visibility for space systems for developing budget and life cycle cost estimates and analyses. Our presentation at the 19th Annual DOD Cost Analysis Symposium will be on work accomplished to date and what we plan to do.

SPACE SYSTEMS:

Upon taking on the task of developing a primer on O&S cost for space systems, one of the first steps was to define what was meant by space systems and to identify what to include in the primer. Examination of the assets that exist in Space Command and elsewhere in the Air Force revealed that the space system could be divided into a ground segment and a space segment.

The ground segment were those assets used to support the space segment. This included control stations, tracking stations, communication, etc. Initially our thoughts were to concentrate our efforts on the ground segment and to address costs associated with the operations, maintenance, and support of computer items, ground stations, and communication required. Then to a limited extent, address the repair costs of on-orbit satellites (i.e. astronauts doing LRU replacement in space) and the retrieval (via Space Shuttle) of low orbit satellites, repair on earth, and placing the satellites back into orbit.

For the most part, the ground segment will be the major part of the primer. However, as a result of our association with the Space System Cost Analysis Group (SSCAG) and their keen interest in this area, an attempt will be made to expand the space segment to include SDI and Space Station as well as satellites. They will be making a considerable input into this area.

In addition, we decided to add another segment called the transportation segment. The transportation segment will be centered on the cost for the Space Shuttle and on Expendable Launch Vehicles (ELV). This segment could very well be a subset of the Space Segment.

GROUND SEGMENT:

In order to be able to estimate the O&S cost for the ground segment you need to have a knowledge of the assets, and an understanding of their functions and of the environment in which they operate. Only then can you proceed to estimate their O&S costs.

The ground segment of space systems play a vital role in the operation and use of space assets. Without the ground segment the satellites would have little or no value. This section of the primer will address the functions of the ground stations, describe the ground networks used by the United States, and identify the types of costs that need to be included. This should lead us to a cost element structure for the ground segment.

There are basically two types of ground stations that relate to the space systems. They are Tracking, Telemetry and Control (TT&C) ground stations and communications ground stations. For the most part, the TT&C ground station is the life blood of the system. They track the satellites, issue commands and control the satellite, monitor the health and status of the satellites, receive telemetry data, make orbit and attitude determinations, process mission data and distribute it to its users. As can be seen, the TT&C ground station is a vital cog in the whole system. Without it, satellites would be useless since the satellites undergo frequent changes in their orbits and the ground station is needed to ensure it is in its proper orbit or to get it there.

The United States has basically three major networks of ground stations associated with space systems. They are the NORAD Space Surveillance Network, the Air Force Satellite Control Network (AFSCN), and the Space Flight Tracking and Data Network (STDN). These networks are not dedicated to any family of satellites. There are some other networks that are totally dedicated to a particular familiy of satellites, e.g. DMSP and GPS.

Each family of satellites needs a command and control center as well as a means of tracking the satellite, and transmitting information to the satellite and receiving information. The command and control center could be totally dedicated to a particular family of satellites, e.g. DMSP at Offutt AFB, or it can share with other satellites as is done at the Satellite Control Facility, at Sunnyvale, CA. The same is true for the tracking stations. They may be totally dedicated (DMSP - Loring AFB and Fairchild AFB) or shared as with the AFSCN with its seven (7) remote tracking stations (RTS). The primer will go into more detail in explaining the various networks.

The key to the whole primer is of course the identification of costs and development of a cost element structure. We are still doing research in this area, however, Atch 1 contains two cost element structures for the ground segment, and comments as to their suitability.

Excluded for consideration in the ground segment are any Space Shuttle processing operations cost. That is, any cost associated with getting the shuttle ready for launch after its return from a prior mission.

SPACE SEGMENT:

This segment will address O&S costs directly associated with assets located in space. It wasn't long ago that there were not any O&S costs associated with space assets - we couldn't get to the satellites ;we could only replace them after they failed.

This all changed with the advent of the Space Shuttle. We now have the ability to extend the lives of satellites through on orbit repair and servicing as well as retrieving of satellites and repairing them on earth. The primer will attempt to expand on this area.

But O&S cost for space assets does not end with satellites. It goes beyond to Space Station and SDI. With the help of the SSCAG, we will attempt to address these two programs in the primer. They have already made some progress in this area. Attached in Atch 2 is a cost element structure (CES) for space systems. It was developed by Mr Claus Meisl, Rockwell International, Rocketdyne Division, Canoga Park, CA. It is his first cut at an O&S cost element structure for space systems.

Mr Meisl's CES may include all appropriate costs but I'm not sure currently. When I think of the space station, I think of it more as an air force base in the sky having functions somewhat analogous to a base. Therefore, I'm currently inclined to believe that we could take the O&S CAIG O&S CES and use it as a foundation for building a space station CES.

SDI on the other hand is different. Envisioned are thousands of assets in space that will require periodic inspections, repairs and upgrading. It will not be manned. It will only require manned access. Therefore, I see it more in line with effort associated with satellites, and whatever CES is developed for satellites should be somewhat suitable for SDI.

Both Space Station and SDI will require some type of ground-based support element. This is something different than what I have currently addressed in the ground segment of the primer.

TRANSPORTATION SEGMENT:

Space transportation could be a potential cost driver associated with the O&S cost of a space system. This is basically space shuttle cost or the cost for ELV and to a minor extent some corresponding ground transportation and support costs.

If maintenance is to be done on a system, then the space shuttle will be involved to some extent. Either to perform the work in space with astronauts, or to retrieve the asset and return it to earth for repair. Correspondingly, to place the asset back into space, either the space shuttle or an ELV will be required. In either case these costs are high. The primer will address these and other costs associated with transportation.

These transportation costs are very significant. Both space station and SDI will require a great deal of space transportation. That is why both programs are looking seriously at the O&S cost issue. The decision on the programs as to their configuration may rest on the transportation issue as it relates to operations and maintainability.

COST ELEMENT STRUCTURES (CES)

Appendix 1 and Appendix 2 contain two cost element structures (CES) the Space System Cost Analysis Group (SSCAG) O&S Cost Element Structure for Space Systems and the traditional OSD CAIG O&S CES respectively. Neither CES truly meet the requirements of an all encompassing CES for the ground segment of a space system. The ideal CES is probably a mix between the two. However, to date the ideal CES has not yet been developed. Additional research is still required. The following is a discussion of some of the shortcomings of each CES.

The SSCAG O&S CES in Appendix 1 is an excerpt of a larger standard Work Breakdown Structure (WBS) for space systems developed by SSCAG. The CES in Atch 1 only addresses the ground segment portion. The ground segment CES is a good attempt in capturing the cost of the ground segment. Most of the directly related costs are included. However, from a military cost estimating viewpoint, some key non-directly related costs are excluded. Additionally, from the way we do business and track costs, there are some other difficulties.

The SSCAG CES does identify most of the costs directly related for the system. However, it excludes most of the support related costs. The structure includes the cost for its prime mission personnel, i.e. operators and maintenance personnel, but it does not include the cost of personnel required to support these people (Base Operating Support personnel) nor other non-pay support costs. From the OSD CAIG O&S CES this would equate to the Installation Support Personnel cost and the Indirect Personnel Support cost.

Here is an example. At a given site there will be personnel directly working on the mission. However, there will also be additional personnel providing support. This could be personnel (Manpower) folks, comptroller, supply, dining hall etc. They are not directly associated with the mission but you still need them. There is also some non-pay support costs also. This could be support facilities, real property maintenance, utilities, routing communication, desks, chairs, other supplies. These are all the cost of doing business. There costs must be included. Additionally, military people rotate assignments - need to include Permanent Change of Station (PCS) costs. Also, people leave the service and new ones come in - need to include acquisition and training costs associated with our military people.

The SSCAG structure does address some real property maintenance (RPM) and utilities costs in its facilities entry. However, this is only for facilities directly related to the mission and not to any support facilities.

The Hardware Maintenance Support is really Replenishment Spares and Depot Maintenance as we in military know it. However, we do business differently. Our "weapon system" is ADP equipment. With most of our ground stations, this ADP equipment is often contractor maintained. With contractor maintenance, for a set fee they provide all labor and material required to maintain the equipment. Consequently, no replenishment spares or depot maintenance is required by the military since it is indirectly provided by the contractor. This is a very significant item for both CES in that it is hard to separate replenishment spares and depot maintenance costs from the contractor maintenance price for ADPE.

The software maintenance could be a problem especially for a command like Space Command where a lot of software maintenance is done in our Off Site Test Facility (OSTF) with military, civilian and contractor personnel. Sometimes it is difficult to isolate cost to a particular system since the personnel may work on various systems and are not totally dedicated to only one system and their time is not accounted for by system.

The SSCAG O&S item for Services seems rather complete to include normal operation and maintenance costs of the sites with the possible exclusion of communication costs. A high expense item can be communication links. It may be covered under the Data Relay Services item, but I'm not sure it is all inclusive. A typical site has a great deal of communication links to include not only communication to and from the satellites but also relay of information to the control and data processing facilities and to users located around the world. This includes a wide gamit of communication means such as voice and data circuits, secure and non-secure, celestrial and terrestrial (Microwave, cable, fiber optics).

The OSD CAIG O&S CES in Appendix 2 is the traditional structure used within the Air Force and is normally well suited to cover all costs of a weapon systems to include all the support costs. Our ground stations have some similarity to a flying wing or missile wing. Our "weapon systems" is really the ADP equipment and it has the support base that is also required for any wing. The CES does account for these support costs to include the PCS and Acquisition & Training which are excluded from the SSCAG O&S CES. However, the OSD CAIG CES also has a few shortcomings which would need some correcting and tailoring to meet our needs.

We do business differently than a flying or missile wing. As stated before, our "weapon system" is ADP equipment and consequently certain things differ in the mission area. The first involves our Unit Mission Personnel. We use many contractors for both operations and maintenance. The current Unit Mission Personnel element is just for military and civilian personnel. Also, the cost for contractors is not standard. They vary significantly from site to site and function to function.

An additional problem is that the price charged for the contractor maintenance personnel also includes cost for the material used, i.e. expendable supplies, and replenishment spares which also abolishes the need for depot maintenance. There is limited depot maintenance accomplished and if so it is more often at a contractor depot not an Air Force depot. To use the OSD CAIG O&S CES as is, would require some type of allocations scheme to identify costs to a particular cost element, or else lump them all into a particular element.

Another deficiency alluded to earlier involved software maintenance. The OSD CAIG O&S CES has it included in Depot Maintenance. In reality, for us it is normally done at our OSTF or on site with possibly military, civilian or contractor personnel using Air Force hardware. It is not depot maintenance. Software maintenance is a big item for our "weapon system" and needs to get the proper visibility.

Other items of concern are communication and consumables. The communication issue here is the same as for the SSCAG O&S CES. Our consumables are not fuel as for an aircraft, but rather ADP supplies - paper, ribbons, tapes, etc. Additionally, we may have high energy consumption in order to operate our radars and ADP equipment.

In summary, there is a lot of good in both CES but there are also deficiencies. We are still conducting research, but should be able to develop a cost element structure that will capture all costs for the ground segment, provide the required visibility, and be traceable to the Air Force cost accumulation system.

SSCAG
O&S COST ELEMENT STRUCTURE
GROUND SEGMENT

01 GROUND SEGMENT

- 01.01 Hardware
  - 01.01.01 Hardware Maintenance Support
- 01.02 Software
  - 01.02.01 Software Support
- 01.03 Services
  - 01.03.01 Ground Segment Management and Integration
  - 01.03.02 Satellite Control Operations
  - 01.03.03 Mission Data Processing Operations
  - 01.03.04 Ground Communications and Control Operations
  - 01.03.05 Tracking Services
  - 01.03.06 Data Relay Services
- 01.04 Facilities
  - 01.04.01 Facilities Operations and Maintenance

SPACE SYSTEMS COST ANALYSIS GROUP
O&S COST ELEMENT STRUCTURE
GROUND SEGMENT

01 Ground Segment

This is a summing WBS entry for the operation of the ground segment. It covers all ground based facilities, equipment and software needed to support the satellite in flight. This element (and its subordinate WBS entries) specifically exclude launch facilities and all ground support equipment that is used in support of flight hardware. This entry can be used whether or not the user of data from this space system has or has not separate and dedicated ground control/processing facilities.

01.01 Hardware

This element covers the ground equipment that controls the satellite, maintains communication with it, and processes flight data. This includes Satellite Ground Control Hardware (Used to monitor and control the satellite vehicle in flight) and its corresponding test equipment (Includes all consoles, dedicated computers and rack-mounted electronics required to execute such functions as telemetry, command processing, orbit and attitude determination, satellite health and status monitoring and sensor control); Mission Data Processing Hardware (Used to process the data stream arriving from the satellite at the ground station. Includes computers, preprocessors, operator consoles and corresponding test equipment); and Ground Communication and Control Hardware (Communication-link hardware used at ground terminals anywhere on the surface of the earth. Includes antennas, r-f equipment, receivers, transmitters, internal communication equipment used within a ground station and the associated test equipment. Includes both satellite-to-earth links and terminal-to-user links). This entry excludes software and services not associated with specific end items.

01.01.01 Hardware Maintenance Support

This element covers the O&S phase activities that are hardware related. It includes follow-on spares, factory rework of failed hardware, and maintenance of factory tooling and test equipment. It excludes logistics pipeline management and on-site maintenance operations.

01.02 Software

This element covers the computer programs for the ground segment. Such software serves to control the satellite, maintain communication with it, and process data from it. This

includes the Satellite Control Software, (Telemetry processing, command formatting, orbit and attitude determination, satellite health and status monitoring, and sensor control), Mission Data Processing Software (Includes functions for data reduction, data base management, and interactive software for operator displays), and Ground Communication and Control Software (Supports the communication links. Includes antenna pointing, signal processing, timing and calibration functions).

01.02.01 Software Support

This entry covers all ground segment software activity in the O&S phase. It includes software trouble-shooting, product improvement, and mission-peculiar program modifications.

01.03 Services

This is a summing element for all ground segment activities that are not end-item oriented. Included are engineering, management and support services; user charges for tracking/relay services; and ground station operations.

01.03.01 Ground Segment Management and Integration

Covers ground segment level integration services that are performed in support of the ground station. Includes program management, systems engineering/integration, training, logistics management, product effectiveness, and the publication of deliverable data.

01.03.02 Satellite Control Operations

This item covers activities for operating and maintaining the equipment used to control the satellite vehicle in orbit (Includes operators and maintenance personnel). Maintenance functions includes scheduled and unscheduled overhaul/repair and operation/maintenance of test equipment. The maintenance functions may also be procured as a purchased maintenance service from the equipment manufacturers.

01.03.03 Mission Data Processing Operations

Same as Satellite Control Operations (01.03.02) except it applies to the equipment used to process satellite data on the ground. Note: Operator functions include computer operations, data reduction and preliminary evaluation, and data base management. However, detailed analysis of the satellite data is considered a user responsibility.

01.03.04 Ground Communication and Control Operations

Same as Satellite Control Operations (01.03.02) except it applies to the equipment used to maintain satellite-to-earth and ground station-to-user communication links.

01.03.05 Tracking Services

This entry covers tracking of the satellite vehicle in orbit. This tracking may be by means of either a ground based network or a space based positioning system such as the Global Positioning System (GPS). These costs would normally be incurred as a user charge to the Program Office.

01.03.06 Data Relay Services

This entry covers any relay operations needed to transmit data from the satellite to the ground terminal. This relay may be through a ground link or a ground/COMSAT communication link, or via a relay satellite such as NASA's TDRS. These costs would be in the form of a user charge to the Program Office.

01.04 Facilities

This item covers the operation and maintenance cost of all facilities for the ground segment. This includes the Satellite Control Facilities (equipment bays, office space and associated HVAC and utilities), Mission Data Processing Facilities (equipment bays, supporting office areas, and associated HVAC and utilities) and Ground Communication and Control Facilities (Includes antenna pads, equipment bays, office areas, and supporting HVAC and utilities. It excludes the antennas, communication equipment, vans and consoles).

01.04.01 Facilities Operation and Maintenance

This item covers all facility related activities in the O&S phase. These include janitorial services; utilities; maintenance of HVAC, plumbing, and electrical equipment; and physical security (if charged directly).

OSD CAIG
O&S COST ELEMENT STRUCTURE

Unit Mission Personnel

- Operators
- Maintenance
- Other (e.g. Unit Staff, Security)

Unit Level Consumption

- Energy Consumption
- Maintenance Material
- Communication
- Transportation

Depot Maintenance

- Electronic Equipment
- LRU/Component Repair
- Support Equipment
- Software
- Modifications
- Other Depot
- Contractual Unit Level Support (e.g. ICS)

Depot Non-Maintenance

- General Depot Support
- Second Destination Transportation

Sustaining Investments

- Replenishment Spares
- Replacement Support Equipment and Spares
- Modification Kits
- Other Recurring Investments

Installation Support Personnel

- Base Operating Support (BOS)
- Real Property Maintenance (RPM)
- Medical

Indirect Personnel Support

- Miscellaneous O&M
- Medical O&M Nonpay
- Permanent Change of Station (PCS)

Acquisition & Training

- Acquisition
- Specialty Training

SPACE SYSTEM OPERATIONS & SUPPORT
WBS DEFINITIONS

SPACE-BASED HARDWARE

Recurring and non-recurring costs of hardware which is dedicated to the on-board operations and maintenance of a space system. This hardware includes consumables. Excluded is hardware which is part of acquisition cost such as:

Space Station Logistics Module:
Integral part of space station with multiple station and payload support functions.

Initial Spares:
Usually accommodated for in acquisition cost to meet Space System IOC requirements.

Condition Monitoring Equipment:
Integral part of Space System, highly interconnected with Space System/Subsystem control.

Communication Satellites (such as TDRSS):
Part of different Space System, accounted for in architecture acquisition cost, has no maintenance function.

SPACE-BASED SOFTWARE:

Costs of software for operating, maintenance, training, condition-monitoring, checkout and inventory control of Space Systems. This software uses onboard computers. Excluded is Space System control software, which is accounted for in the Space System acquisition cost.

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SPACE-BASED SERVICES

Costs of services which are required to operate, support, maintain and repair/replace the Space System (including its payloads) and are provided by onboard personnel of a manned Space Station or by maintenance crews transported to man-tended stations or platforms. All other operations and support activities which are performed by ground personnel are accounted for in the ground segment of Space System Operations and Support.

SPACE-BASED FACILITIES

Costs of in-orbit facilities for hardware, fluid or ordnance storage, maintenance functions and maintenance support which are required to support the space system.