Hosted Payload Guidebook

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1. INTRODUCTION

1.1. PURPOSE OF THIS GUIDEBOOK

As DoD, NASA, and other U.S. government agencies increasingly consider alternative means of getting payloads to orbit in order to save time and money, greater consideration is being given to having those payloads hosted on commercial satellites. While the use of commercial satellites to host government payloads has proven effective, it is an approach that has a range of risks as well as rewards. Successfully launching a payload on a host satellite requires an understanding of the nature of commercial satellite business and technical operations. This guidebook is intended to clarify those operational issues and help government customers plan to use the process to their best advantage.

1.2. RATIONALES FOR FLYING HOSTED PAYLOADS ON COMMERCIAL SATELLITES

The two principal advantages for a hosted payload owner of flying on a commercial mission versus a government-sponsored mission are: (1) the faster tempo of commercial programs, and (2) the lower cost. Typical schedules for commercial satellite deployments from concept definition to operations are around 32 months. Comparable government schedules can be five to seven years, and sometimes longer if the primary government mission is complex. And while many science missions have been limited to low earth orbit (LEO), given the expense of getting to geostationary orbit (GEO), the use of hosted payloads on commercial GEO satellites provides a relatively low cost opportunity for access to higher orbit.

Other advantages include: a reliable and predictable launch schedule, with a large choice of launch vehicles (commercial operators usually are on the manifest of several launchers, in order to be better prepared for contingencies); the use of existing mission support facilities; and the fact that, once on-orbit, the primary payload operator will take care of all operations and maintenance of the host spacecraft as well as (if requested) data downlink and processing. In addition, since commercial spacecraft are insured, the hosted payloads on those spacecraft can also be insured, helping defray the costs of a replacement mission in the event of a launch failure.

Disadvantages include the inevitable limitations on mass, volume, and power consumption that the status of “secondary” payload often entails (while some hosted payloads may effectively hold primary status, this is not typically the case). In addition, there is the requirement to adhere to the strict procurement, construction, and launch schedules for commercial satellites, which are typically much less flexible and more driven by time constraints than their government counterparts. Another disadvantage, often overlooked but important for Earth observation missions in particular, is that although the number of commercial geostationary spacecraft launched in a particular year is quite large, each of them will occupy a fixed orbital slot with limited view of the Earth. This allows for multiple observations a day, but not a global view.

The amount the hosted payload owner would have to pay to the primary payload operator is difficult to assess, and is likely to vary considerably. Key variables include the size and mass of the payload, what ancillary services are desired to support payload operation, whether payment is up-front or over the satellite lifetime, opportunity cost to the host, whether it enhances the host system’s business case, choice of launch vehicle, insured or not insured, etc..

A further area to be considered is the fact that the primary commercial payloads typically have a lifetime of 15 years and often more. Many hosted payloads, by contrast, have a projected life of five years or less.

This mismatch is less of an issue for communications payloads, which may be designed to operate for as long as the primary spacecraft. On the other hand, this long host platform life may present an opportunity for enhanced data continuity that has not typically been available to past payload missions.

1.3. BACKGROUND AND EXPERIENCE

All of the major commercial GEO fixed satellite operators (Eutelsat, Intelsat, SES, and Telesat) have publicly declared themselves receptive to the idea of hosting payloads, as have non-GEO users such as Iridium and ORBCOMM, and a number of these operators have hosted government payloads. Outside of the global operators, INSAT has hosted several ISRO payloads, all of them either scientific or technology demonstrators in nature.

Among the first major U.S. government payloads hosted on commercial GEO satellites were the two L-band Wide Area Augmentation System (WAAS) Packages operated by subcontractors Telesat and Intelsat for the prime, Lockheed Martin, under contract to the FAA. One WAAS payload is carried on Telesat's Anik F1R, built by Astrium and launched in September 2005. The other WAAS payload is on Intelsat's Galaxy 15, a satellite built by Orbital Sciences and launched in October 2005 (the satellite was part of the PanAmSat fleet when launched). More recently, two demonstration payloads have been contracted by the DoD. First of these is the Internet Router in Space (IRIS) hosted on Intelsat's Space Systems/Loral-built Intelsat 14 satellite, launched in November 2009; the second is the Commercially Hosted Infrared Payload (CHIRP) sensor which will be integrated on the SES WORLDSKIES' SES-2 satellite under construction by Orbital Sciences for launch in late 2011. Also in the construction stage is an operational UHF package which the Australian Defence Force (ADF) contracted for launch on Intelsat 22, a Boeing-built 702B bus, in mid-2012. Most recently, the DoD has contracted for a UHF payload to be hosted on the Intelsat-27 spacecraft, to provide capability to complement the existing UHF Follow-On (UFO) and future Multi-User Objective System (MUOS) satellites.

While each of these programs has provided insights that are incorporated in this guidebook, the primary lesson, noted in interviews and workshops among operators and manufacturers, is the need for adequate planning and realistic expectations on the part of the hosted payload owner. The earlier the hosted payload's requirements are incorporated in the planning process for satellite procurement, the greater the likelihood that they will be accommodated.

1.4. COMMERCIAL SATELLITE FORECAST

To provide some context for understanding the potential opportunities for putting a hosted payload on a commercial GEO satellite, Table 1 lists known planned satellites by Eutelsat, Intelsat, SES, and Telesat for the period 2011–2016, including their launch year and their planned orbital locations. Although all of the major operators have indicated they would be willing to host payloads, practical constraints indicate that the larger the bus and the longer the lead time, the better the chances are that the hosted payload's requirements will be accommodated. Those satellites marked "HR" are hypothetical replacements anticipated to be ordered to replace existing spacecraft, but have not been contracted.

Table 1: Satellites Planned or Anticipated to be Ordered by Major Operators, 2011–2016

Satellite Name	Owner/Operator	Launch Year	Location (°E)
Eutelsat W3C	Eutelsat	2011	7
Atlantic Bird 7	Eutelsat	2011	7.2
Intelsat 17	Intelsat	2011	66
Intelsat 18	Intelsat	2011	180
Intelsat 19	Intelsat	2011	166
Intelsat 23	Intelsat	2011	307
SES-5/Sirius 5	SES	2011	4.8
SES-2	SES	2011	273
Astra 1N	SES	2011	19.2
SES-4	SES	2011	338
SES-3	SES	2011	257
Telstar 14R	Telesat	2011	297
Eutelsat W6A	Eutelsat	2012	21.6
Intelsat 22	Intelsat	2012	72
Intelsat 20	Intelsat	2012	68.5
Intelsat 21	Intelsat	2012	302
Astra 2F	SES	2012	28.2
Anik G1	Telesat	2012	252.7
Nimiq 6	Telesat	2012	269
Eutelsat W5A	Eutelsat	2012	70.5
Eshail	Eutelsat/ICT Qatar	2012	25.5
SES-6	SES	2013	319.5
Astra 2E	SES	2013	28.2
Eurobird 3-HR	Eutelsat	2014	33
EUROBIRD 1-HR	Eutelsat	2014	28.5
Astra 1H-HR	SES	2014	19.2
Astra 2G	SES	2014	28.2
Astra 5B	SES	2014	31.5
Intelsat 12-HR	Intelsat	2015	45
Intelsat 1R-HR	Intelsat	2015	310
NSS 11-HR	SES	2015	108.2
AMC 6-HR	SES	2015	288
TELSTAR 12-HR	Telesat	2015	345
ATLANTIC BIRD 2-HR	Eutelsat	2016	352
Eutelsat W3A-HR	Eutelsat	2016	7
Intelsat 10-HR	Intelsat	2016	TBD
Intelsat 805-HR	Intelsat	2016	304.5

In addition to these spacecraft, Iridium is now building a new LEO constellation, and had stated its interest in hosting payloads on some or all of these spacecraft, planned for a series of eight launches between the first quarter of 2015 and the first quarter of 2017.

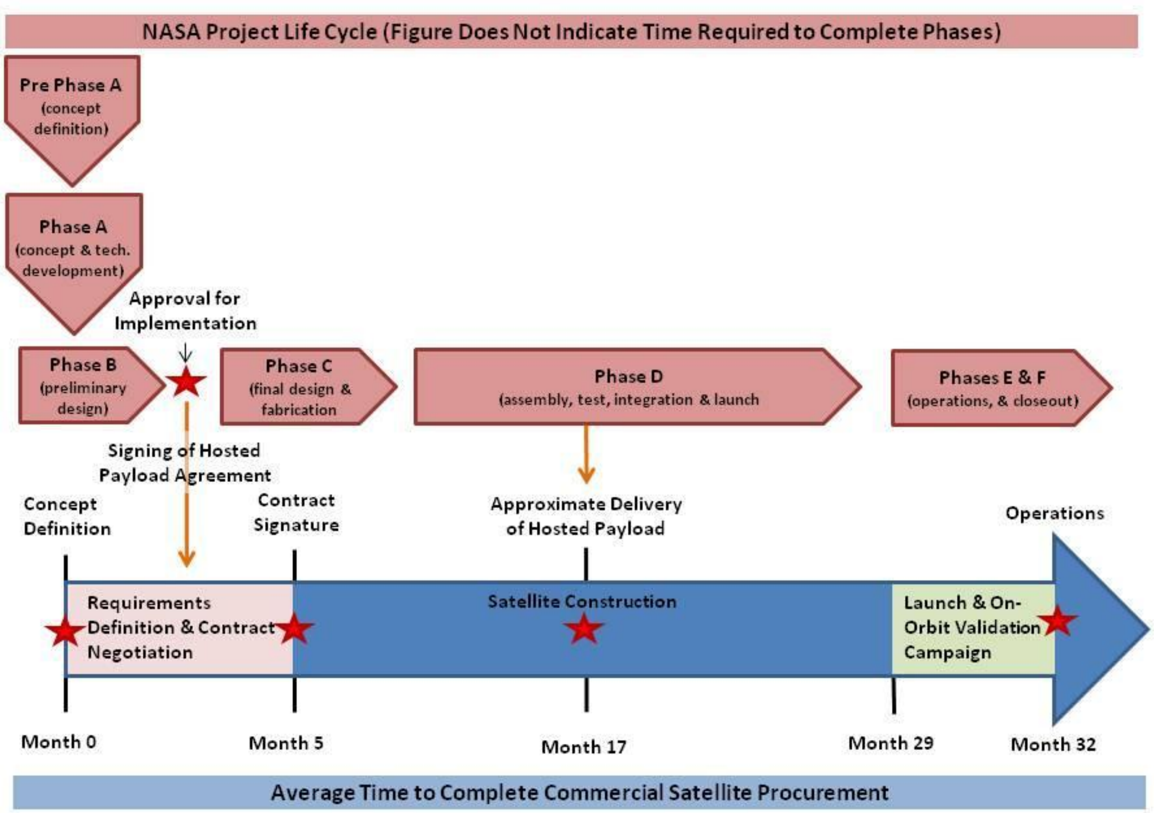
2. BEFORE CONTRACT SIGNATURE – TECHNICAL ISSUES

2.1. COMMERCIAL SATELLITE PROJECT TIMELINES

The average pace of commercial satellite procurement from concept definition to operations is around 32 months. This process begins with five months for the requirements definition, RFP generation, proposal evaluation, and contract negotiation. The satellite construction itself lasts anywhere from 18 to 30 months, with 24 months a typical duration. The launch campaign, orbit raising, and in-orbit testing together take up another two to three months. It is very important for the owner of the hosted payload to realize that while accommodation can be made in the negotiation phase to address all payload needs, once set this schedule is usually inflexible. The satellite owner typically is time constrained and unwilling to let the construction or launch schedule slip due to considerations specific to the hosted payload.

For purposes of comparison, NASA space flight projects are organized into incremental life-cycle phases that allow managers to assess management and technical progress. The timing of specific activities within each phase depends on the particular schedule requirements of a given project; and some activities may occur out of the usual order. Figure 1 relates the NASA Project Life Cycle to the typical timeline required for a commercial satellite procurement, showing where the development of a hosted payload following the NASA Project Life Cycle must interact with the development schedule of the host satellite.

Figure 1: Comparison of NASA Project and Commercial Satellite Development Timelines



The typical turnaround time is also influenced by the maturity of the bus and, to a smaller extent, that of the payload components. Satellites based on mature busses might feature lower than average turnaround times. On the other hand, a newer, "state-of-the-art" bus might have extra room available to accommodate hosted payload components, particularly if the regular payload definition has not kept pace with the higher mass and power that is available.

It is essential for the hosted payload owner to approach the satellite operator early in this 32-month window so that the contract between host owner and operator can be finalized well before the contract is signed with the satellite manufacturer, and preferably to enable the hosted payload interface definitions to be incorporated in the RFP. Some operators and satellite manufacturers prefer that the contract between the hosted payload owner and the satellite operator should be finalized six to nine months **before** the signature of the contract with the satellite, in order to avoid platform incompatibility issues for the hosted payload. At the same time, it is also recommended government payload owner decide during the pre-phase A stage of their mission whether or not they intend for the mission to be commercially hosted versus being accommodated on a dedicated government program. In addition, it is worth noting that, in general, "access to space" must be specifically addressed during Phase B. Without confidence of space access defined, obtaining a Phase B award is jeopardized.

It also is worth noting here that the commercial construction turnaround schedule of around 24 months is far more aggressive than the typical government contract schedule, which is five years. Within the government realm, there are numerous rounds of reviews and long stretching periods between reviews. The government might in principal favor a shorter commercial schedule, but must be prepared to accommodate it and make decisions along the same time lines. This might be difficult given the hierarchy and decision making process within government agencies.

All satellite operators and manufacturers will publicly state that they try to adhere to the schedule stated above. Issues such as contract amendments (for example, to change the coverage area of the beams), or placement of the hosted payload on a prototype bus that is not yet fully commercialized, can of course cause delays compared to the average schedule.

2.2. COMMERCIAL SATELLITE PLATFORMS

2.2.1. Background

There are six major manufacturers of commercial GEO communications satellites: Thales Alenia Space, Boeing Corporation, EADS Astrium, Lockheed Martin Commercial Space Systems, Orbital Sciences Corporation, and Space Systems/Loral. All six are currently building commercial satellites that will operate at GEO, as well as the NGSO Iridium constellation.

Although every platform comes with limitations in volume, mass, and power, it is notoriously difficult to get detailed information from the manufacturers on the maximum capabilities of their bus. This is because the manufacturers are constantly updating these platforms, but also because other design factors, such as a shorter orbital maneuver life, can be traded off for more mass or power.

Table 2 illustrates some recent examples of mass and power capabilities that could be found for state-of-the-art buses for each of the major six operators.

Table 2: Typical Power and Mass Values for Major Commercial Satellite Buses

Manufacturer	Bus	Power (KW)	Dry Spacecraft Mass (kg)
Thales Alenia Space	Spacebus 4000	16	2800
Boeing	BSS 702	18	3800
EADS Astrium	Eurostar 3000	15	2000
Lockheed Martin	A2100	16	2800
Orbital Sciences	Star 2	7.5	2250
Space Systems / Loral	SL-1300	20	3200

Note that manufacturers are constantly improve the capabilities of their platforms, thus the "typical" values reported above are frequently updated. Nearly all of the power customarily is used to support the primary payload and the bus functions. Depending on the requirements of the primary payload, there is generally limited power available for the hosted payload, however, early negotiations with the satellite operator and manufacturer can often yield more flexibility and capacity.

2.2.2. Available Real Estate for Hosted Payloads

Manufacturers of communications satellites that offer hosted payload capacity typically make space available for hosted payloads on the nadir, or Earth-facing, surface of the satellite, but can also accommodate non-Earth facing requirements for space weather, space situational awareness, or other applications. This is also the case if instruments or R&D equipment has to be accommodated. If the hosted payload includes communications equipment, additional space has to be made available inside the communication panels.

Table 3 gives a general idea of the availability of these resources for hosted payloads on selected satellite manufacturer/primary payload operator combinations at the smaller end of the scale, as reported by Iridium and Orbital. The information presented in this table is an approximation only, and shows the low end opportunity. Specific availability varies on a case-to-case basis depending upon the requirements of the primary payload; for larger GEO satellites, such as those built by Boeing, Lockheed Martin, and Space Systems/Loral, the resources available for hosted payloads will be considerably greater than those shown here. A key consideration is that small hosted payloads (which only draw resources from system budget margins) can be accommodated at significantly lower cost than those hosted payload which demand bus hardware changes.

Table 3: Available Resources for Hosted Payloads on Selected Buses

Primary Operator Information			Available "Real Estate" For Hosted Payloads			
Bus Manufacturer	Bus Model	Example Operators	Payload Mass (Max)	Payload Volume (Max)	Power	Data Downlink
Thales Alenia Space	Iridium NEXT	Iridium	50 kg	30 x 40 x 70 cm	50W avg. 200W peak	Up to 1 Mbps
Orbital Sciences Corporation	STAR Bus	Any	~60 kg	~ 24" x 30" x 28"	Depends on primary payload	Up to 75 Mbps

SOURCE: Iridium. www.iridium.com/Download/Attachment.aspx?attachment ID-921
SOURCE: Orbital Sciences. www.orbital.com/newsinfo/publications/HostedPayload_Factsheet.pdf

In addition to physical and power constraints, hosted payloads must also coordinate line of sight and electronic interference issues with the primary payload. Frequency co-ordination between the hosted payload operations and that of the commercial transponders on the hosting spacecraft is an issue that must be addressed between the entity seeking to take advantage of hosted payload opportunities and the commercial operator offering the opportunity. In addition, the hosted payload must be sized and placed on the hosting spacecraft in such a manner as to not impinge upon the look angle requirements of the hosting vehicle's antennae and attitude sensors.

These matters must be addressed on a case-by-case basis, and are optimally addressed by the open and timely exchange of design trade studies and requirements among the primary payload operators, the spacecraft manufacturer, and the agency providing the hosted payload. These requirements may also dictate the selection of a host satellite based on orbital location vs. other factors. This should be completed well in advance of the issuance of the satellite RFP, as addressed above.

2.3. OTHER TECHNICAL ISSUES

2.3.1. Standardization of Hosted Payloads

Many parties have raised questions regarding whether the government and industry should agree on a set of standardized interfaces for hosted payloads. For the time being, "standardized" interfaces for hosting payloads are rare and only used in cases of multiple builds. It is harder to make the case for "one-of-a-kind" payloads that encompass most R&D programs.

It should be noted that satellite manufacturers have historically been somewhat resistant to the idea of standardizing the hosted payloads interfaces, because it limits the owner/operator flexibility. In addition, there is the risk that the operator will throw away valuable "real estate" on the spacecraft if the envelope of size, mass, and power requirements allocated for the hosted payloads exceeds its actual needs. There has also been a concern over creating an alternative to the proprietary interfaces, developed at great expense by each manufacturer, in favor of some common standard across multiple bus types.

More recently, however, manufacturers are openly promoting their busses as having the capability to support hosted payloads, as operators have seen such payloads as a valuable part of their business planning. Standard interfaces also allow flexibility in choice of host spacecraft, because many of the hosted payloads would become interchangeable. Standardized interfaces can allow the satellite manufacturers to sell access to space to third party clients by contracting with their customers to "allow" a hosted payload to be placed on their spacecraft (by the manufacturer) in exchange for price reduction on the host spacecraft.

2.3.2. Telemetry and Commanding

Usually, the telemetry signals to the hosted payload are provided through a standard serial interface and the science instrument data will be downlinked on a leased transponder. This telemetry is subject to various operational conditions of the satellite, discussed in the Operations section of this document. In case the mission data link (see below) requires a detailed ephemeris link or a timestamp for correct interpretation (which is often the case for scientific payloads), the primary payload operator should agree to make these data available in a timely manner, an issue that should be addressed in the contract negotiations.

Within the world of commercial satellite operators, the command link between the communications payload (which would include the hosted payload) and the rest of the spacecraft is standardized for each bus/platform. Enforcing the same standard upon potential hosted payloads is possible and desirable. It is imperative that the owners/operators of the hosted payload familiarize themselves with the command data stream of the host satellite before it gets finalized during the satellite procurement process. If this happens early enough in the process, it will be easy to incorporate the needed commands for the hosted payload within the regular command stream of the satellite.

The hosted payload owner can of course insist on its own command link; however, that would impose additional demands on the platform/bus and require earlier involvement on the part of the hosted payload owner within the overall RFP process and construction period.

2.3.3. Data Processing

The interface of the mission data to the communications payload presents another challenge, as it is difficult to standardize even for the same bus/platform due to the varying requirements of the sensor or communications equipment that would transmit the mission data. Some spacecraft manufacturers promote an approach whereby the hosted secondary payload passively taps into the primary communications payload at a standard point, such as between the input multiplexer and the RF power amplifier redundancy network. The hosted secondary payload data are sometimes incorporated within the primary payload communications system, and in those cases the hosted payload operates essentially as another terrestrial user.

Another approach is to keep and process the hosted payload data completely separate from the primary payload data. This approach is likely to be more expensive and will require more planning on the part of the hosted payload owner in that the mission data link has to be accommodated on the platform as well as the primary payload links.

3. BEFORE CONTRACT SIGNATURE – CONTRACTUAL ISSUES

3.1. COMMERCIAL CONTRACT BASICS

A commercial satellite construction contract contains 30-40 different elements, and as shown in Table 4, only a limited number address the technical aspects of the satellite, with most focused on legal rights and liabilities.

Table 4: Basic Articles Included in a Commercial Satellite Manufacturing Contract

Definitions	Acceptance of deliverable items other than the satellite	General indemnification	Public release of information
Scope of work	Transfer of title and risk of loss	Termination for convenience	Notices
Deliverable items and delivery schedule	Orbital performance incentives	Liquidated damages	Risk management services
Price	Corrective measures in satellite or other deliverable items	Termination for default	Order of precedence
Payments	Representations and warranties	Dispute resolution	Ground storage
Purchaser-furnished items	Changes	Inter-party waiver of liability for a launch	Contractor personnel
Compliance with laws and directives	Force majeure	Limitation of liability	Subcontracts
Access to work-in-progress	Purchaser delay of work	Disclosure and handling of proprietary information	Intellectual property
Satellite pre-shipment review (SPSR) and delivery	Intellectual property indemnity	Contract technology escrow	Tender requirements
Acceptance of satellite, launch support, mission operations support, and in-orbit test			

While contracts for satellites that might accommodate a hosted payload (or that are designed from the beginning with such a payload already planned) are all different, some basic, common definitions can be provided to assist the government user of that payload:

- **Hosted Payload(s):** An instrument or package of equipment that is affixed to a host spacecraft and operates in orbit making use of available capabilities of that spacecraft, including mass, power, and/or communications.
- **Hosted Payload Customer:** Party entering a contract with host spacecraft operator for either: 1) access to spacecraft physical resources for use by a payload procured by the customer and furnished to the Satellite Operator (CFE), or 2) access to data from a payload procured by the Satellite Operator and integrated with the spacecraft.
- **Hosted Payload Contractor:** Manufacturing contractors and their subcontractors responsible for building the hosted payload.
- **Hosted Payload O&M Agreement:** Management agreement that will dictate the terms associated with Satellite Operator's responsibilities for operations and maintenance of the Hosted Payload.
- **Host Spacecraft:** A satellite bus with subsystems capable of maintaining operation of multiple payloads; the entity holding the primary contract with the spacecraft manufacturer is considered to be the host operator.
- **Launch Date:** The designated date from the launch manifest on which the host spacecraft is to be launched into space.
- **Launch Service Provider:** Party contracted by the host operator to launch the spacecraft to its designated orbit.
- **Satellite Contractor: S**atellite manufacturing prime contractors and their subcontractors
- **Satellite Operator:** Owner/operator of the host spacecraft.
- **Satellite/Payload Manifest:** The schedule that indicates specific spacecraft and Hosted Payload in combination with the associated launch vehicle

- **Systems Integrator:** Party responsible for overall integration of the Hosted Payload with spacecraft (this is most likely either the Satellite Contractor or the Hosted Payload Contractor, but might be another entity).
- **Financing Agency:** Commercial entity providing financing to customer, Satellite Operator, Satellite Contractor, Hosted Payload Contractor, and/or Systems Integrator to enable development, construction, launch, and operation of hosted payload mission.

3.2. CONTRACTING PROCESS – INITIAL STEPS

The first decision to be made by a government agency in considering the use of a commercial satellite as the host of a government payload is whether to use a full and open RFI/RFP process or use sole sourcing. Next, a decision is required on how far the agency wishes to get involved in the satellite contractual issues, or how much they can be avoided. This is a function of the type of hosting arrangement chosen.

When the government is acquiring only data services using a payload built and integrated by the host company or a third party, the government will have no responsibility to provide any satellite hardware. The hosting company will provide full disclosure to the government of development progress of the hosted payload, satellite and the launch vehicle. If the government has pre-paid for data services with the expectation that the service would be available by a certain date and the payload is subsequently late to orbit, the satellite owner may be penalized. The government, though, will also have no signature authority over the design, manufacture, test, or launch of the hosted payload, satellite, or launch vehicle. Test compliance may, however, be a requirement of acceptance by the government customer and initiation of payment for services.

However, if the government hosted payload customer plans to provide satellite hardware, or to play a role in the design and development of the hardware, strict adherence to the delivery schedule is required. If delivery is late, the hosting company will be under no obligation to delay the launch or to include the hosted payload. In such cases, government would be required to fulfill financial obligations to compensate the hosting company for lost opportunity in accordance with negotiated terms in the contract. Since a portion of the hosting fee is to compensate the owner/operator for the potential reduction in the life of the primary payload due to the additional propellant used to launch and maintain the hosted payload mass on orbit, and that loss to the owner/operator would not be realized until the end of life of the spacecraft, a portion of the hosting fee may be refundable in the case of a launch failure or demise of the satellite prior to the EOL of the hosted payload contract. This arrangement needs to be negotiated upfront to make sure financials for a hosting fee and annual operation fees can be differentiated.

During this initial phase, government and potential host companies will conduct a feasibility study for mission fit and definition, including criteria such as required schedule and technical capabilities. Provisions should be included upfront if the government seeks options for additional, identical, hosted payloads on multiple satellites, including definition of option exercise dates, cost, schedule, and related factors.

To understand the contracting steps and roles, the following is a description of a capability lease acquisition process, one for which there are a number of recent examples, as noted in the background section:

- Payload/mission has a single government customer/purchaser of capability
- The government user defines capability requirements
- The payload is procured by a satellite operator based on government customer specification and sign-off
- The satellite operator or a third-party contractor integrates, launches, and operates the payload

- The satellite operator or third-party contractor provides capability to the government customer under a Service Level Agreement (SLA)
- The government customer procures capability for a defined period of time
- Satellite operator provides O&M support for capability, including payload status

These contracts raise a series of government acquisition issues that need to be addressed up front by all parties for the overall process to be successful:

- Use of sole-sourcing
- Termination liability
- Payment structure and use of multi-year contracts
- Acceptance of tight and immutable commercial schedules
- Challenges of multi-party contracts (e.g., government, satellite operator, satellite manufacturer, hosted payload manufacturer)

The pre-contract design phase should include the identification, responsibilities, and interworking of different parties. These parties include the owner of the hosted payload, the manufacturer of the hosted payload, the owner/operator of the commercial satellite that will host the payload, the manufacturer of that satellite, and the launch services provider. This phase also needs to address technical specifications for the payload, interfaces, ground segment, and telemetry and payload data, as discussed in Section 2.

To provide context and background for new hosted payload customers, Figure 2 below provides a summary of examples of these contracting issues as applied to three ongoing hosted payload programs (note that the contract values may include items beyond just the hosting of the payload).

Figure 2: Contracting Issues for Several Hosted Payload Programs

	CHIRP	NextView	WAAS
Organization *Contract Size*	*AF SMC* *$65M*	*NGA* *$500M*	*FAA* *$597M*
1 *Justification / Rationale*	• Experimental risk-reduction effort under the 3GIRS program	• Mitigate potential gap in availability of commercial imagery	• Mitigate gap in flight coordinate accuracy within the US
2 *Sourcing*	• Sole-Source • Initiated via unsolicited proposal	• Competitive bid (2 awardees)	• Competitively bid to prime (not to hosting platform)
3 *Asset Control / Ownership*	• Contractor-owned and operated sensor payload; near-unlimited data rights	• Commercially-owned asset; • Broad DOD- data rights	• Commercially owned and operated space-based assets • Mix of USG and Commercial ownership of payloads
4 *Payment Structure*	• Planned and event-based payments • Termination liability clause limited amount of obligation	• Capital investments followed by monthly flat-fee data rates ($12.5M a month)	• Multi-year contract for uplink and satellite services from USG to Prime • Shorter contracts to operators • Monthly payments for service
5 *Quality Assurance*	• Cost included operation and delivery of data for 12 months	• SLA included operation and data delivery	• SLA for satellite services

From the government customer's perspective, it is also important to understand and apply the relevant federal acquisition regulations. Figure 3 summarizes key elements to be considered.

Figure 3: Hosted Payload Government Acquisition Issues

Sourcing

- Sole Source Justifications
  - **FAR 6.302-1:** Unique capability to meet requirements
  - **FAR 6.302-2:** Urgent and Compelling Need

Asset-Control

- Termination liability
  - **FAR 232.705.70:** Limitation of Government Liability
- Data Rights
  - **Title 50 License:** data provided to USG entities can be shared between USG users (unlimited government licensing); data can be resold to commercial stakeholders

Quality Assurance

- Performance Reviews
  - **FAR 52.246-4/7000:** Inspection and Acceptance clause permits a Government entity to implement performance-based standards and reviews

Payment Structure

- Multi-Year Contract for the Acquisition of Property
  - **10 USC 2306b:** Title 10 was amended in 1993 to allow DOD, DHS and NASA to enter into multi-year contracts for the acquisition of property
  - **FAR 17.101:** provides authority for a multi-year contract up to 5 years, with a ceiling of $500M and a maximum termination liability of $20M
    - *Applicable to DOD, NASA and Coast Guard*
    - *Used as the legal basis for ClearView/NextView for the acquisition of imagery*
  - **15 USC Chap 84, 5806:** authorized NASA and NOAA to enter into multi-year anchor tenancy contract with termination liability
- Multi-Year Service Contract
  - **FAR 217.171:** Authorizes USG entity to enter a multiyear contract for services; statutorily limited to 5 years
  - **AIR-21 P.L. 106-181:** The Aviation Investment and Reform Act allows the FAA to set up programs to test benefits of long-term contracts greater than 5 years
- Co-Investment
  - 10 U.S.C. 2371: Authorizes gov't and commercial cost-sharing

3.3. CONTRACTING PROCESS – OVERALL PRE-LAUNCH RESPONSIBILITIES

3.3.1. When Government Does Not Provide the Hardware

In this situation the hosted payload contractor is responsible for the design, development, supply, production, test, and certification of payload under contract with the government customer and in coordination with the satellite contractor (if different) as well as with any additional system integrator. By the time of the Preliminary Design Review (PDR), the hosted payload customer and host satellite operator have executed the payload construction contracts with the hosted payload and satellite manufacturers, respectively; in almost all cases, these should have been concluded considerably earlier. The PDR will also require the completion of the preliminary hosted payload specification and integration plan, including the Interface Control Document (ICD), with the host spacecraft. The final hosted payload specification and integration plan will be completed by the Critical Design Review (CDR), along with the final concept of operations for the hosted payload.

In addition to the above documents, the satellite operator and satellite contractor will need to complete several other documents, including:

- Safety Design Hazard Report
- Interfaces Preliminary FMEA
- Security Plan (if applicable), including ITAR
- Detailed description of customer-furnished equipment
- Export licenses for shipment to the launch facility

- ITU coordination and FCC licensing for operations at the appropriate frequencies and longitudes

3.3.2. When Government Provides the Hardware

In the case where the government provides the hosted payload hardware, the responsibilities of the payload customer and the satellite operator shift. The hosted payload customer takes on a number of responsibilities in the coordination and support of payload development prior to integration to the host satellite. These include the establishment of the development timeline of the hosted payload and expected delivery date for integration, signing a contract with the hosted payload manufacturer and (if appropriate) the payload integrator, and signing a separate contract with the host satellite operator and/or systems integrator. During this time the hosted payload customer is also responsible for the identification of any technical changes to the payload that could impact the spacecraft or its ability to support its primary mission as well as any other hosted payloads it may be carrying. The hosted payload customer must also conduct a technical qualification of the payload and provide a qualification report prior to delivery of the payload for integration onto the host satellite.

The hosted payload customer also has additional responsibilities after the launch of the host satellite. The customer is typically responsible for turning on and checking out the payload, performing any required acceptance testing, and starting normal operations. The customer must also monitor the payload's operations to ensure that it does not interfere with other aspects of the host spacecraft, and provide regular status reports. Specifics about these aspects of the hosted payload mission are discussed in the Operations section of this document.

The satellite operator (or satellite manufacturer), meanwhile, has a number of responsibilities it must fulfill for the hosted payload customer. This includes providing the interface specification for integrating the hosted payload with spacecraft and a hosted payload qualification document that certifies compliance with the interface specification. In many cases this responsibility will also extend to the ground system network interfaces within the ground system ICD. The satellite operator will also facilitate interaction among the satellite manufacturer, hosted payload customer, and hosted payload manufacturer, to cover issues such as schedule and launch readiness, development of a test plan for delivery of the flight-qualified hosted payload to the satellite manufacturer, and status updates on any issues that could impact the mission. These responsibilities and deliverables would be detailed in a separate contract with the hosted payload customer.

The satellite operator is also ultimately responsible for the launch of the spacecraft and insertion into its specific orbit. In addition, the operator will need to develop an O&M agreement with the payload operator, covering issues such as operational communications and coordination between the spacecraft operations site and the customer's hosted payload operations site. This agreement can also include operational support for the hosted payload, including turn-on, initial checkout, and calibration, as well as delivery of hosted payload data to the customer once the payload begins operations.

3.4. PAYLOAD OPERATION AND PRIORITY

In most cases the hosted payload has secondary priority, although the specific details are negotiable.Even so, the operator will make its best efforts to maximize hosted payload operations, subject to primary payload priorities. The hosted payload must not directly or indirectly disrupt the primary mission. Responsibility for hosted payload operations generally rests with the satellite operator. Any exceptions to these guidelines must clearly define each party's responsibilities under both nominal and anomalous operations.

Subject to the details of the hosted payload contract, operation of the hosted payload can be suspended if operation is deemed to pose a hazard (either imminent or long-term) to the primary mission. Operation of the hosted payload can be temporarily suspended without prior notice in the event of a satellite anomaly. Operation of the hosted payload can be permanently suspended if insufficient satellite resources are available to operate it in accordance with satellite operations priorities; this is no different than for secondary payloads on government host spacecraft. In such circumstances, any compensation to the government in the case of suspended hosted payload operation shall be in accordance with negotiated terms in the contract between the hosted payload customer and satellite operator.

3.5. GENERAL CONTRACT TERMS

3.5.1. Payment Structure

Payment amounts and schedules are negotiated separately, depending on issues such as whether data services only or a CFE payload are provided. The contract can include payment for items such as:

- Development costs of the payload or required spacecraft modifications
- Operations & maintenance
- TTC&M
- Communications services ancillary to the payload activity (e.g., transponder lease, data receipt and processing)

Payments may be made upfront for a CFE payload operated by the government or on a continuing basis as services are provided by the host satellite operator, especially for data or maintenance services. Other specialized financial terms may include a need for the satellite operator or the hosted payload integrator to execute the Certificate of Commercial Item (Form 004-020COCI) with the indemnity provided by the company limited to fines, penalties and reductions incurred as a result of the company's gross negligence or willful misconduct. The contract may also require agreement that all taxes and fees incurred as a result of providing services on the government's behalf, related to the hosted payload, shall be paid by the government.

It is important to understand that commercial satellite contracts typically include a milestone payment schedule that almost always includes substantial payments to the manufacturer well before launch, to compensate the manufacturer for the substantial investments made in parts, material, and labor well before delivery of the spacecraft to the launch site. The hosted payload operator might be required to contribute to the milestone payment schedule as well, sometimes years before the hosted payload will be operational.

3.5.2. Liabilities and Other Rights/Responsibilities

General categories of liability are defined to cover:

- Launch delay
- Launch failure
- Hosted Payload delay
- Hosted Payload failure
- Host Satellite failure
- Hosted Payload partial loss
- Host Satellite partial loss
- Reduced station-keeping ability

- Reduced design life or orbital maneuver life
- Reduced power (e.g. damaged solar panels)
- Other anomalies (e.g. reduced telemetry)
- Primary mission precedence
- Orbital slot placement/maintenance (or changes)

Given the high degree of potential for incompatibility of development/deployment schedules between the hosted payload manufacture and that of the host satellite, there are generally financial obligations under the following scenarios:

- Cancellation by the government
- Exclusion of hosted payload from satellite for specified reasons
- Failure of hosted payload to perform properly (if not CFE)
- Failure of government to provide hosted payload in time for specified launch (if CFE)

There are some elements of shared risk as well. A change in the launch service provider's launch manifest is typically considered "no fault" to either party. In cases of hardware issues, the government may be able to off-ramp the hosted payload from the original host onto the next feasible spacecraft's on-ramp if those conditions are specified in the contract. Such changes may involve engineering costs to the operator that must be compensated by the government.

For data and intellectual property rights, with the exception of the hosted payload itself, the host satellite operator does not grant any rights to government regarding the design and operation of the satellite. The government, in turn, retains the right to license the hosted payload design in accordance with negotiated terms. Rights to the hosted payload data must be negotiated in the contract. This may include limited or unlimited data rights for the host satellite operator, as well as terms under which the satellite operator is authorized to share hosted payload data and findings with other organizations. If the hardware is GFE, the contract may include requirements to deny use of the data by others, even after the government's use of the hosted payload has terminated.

The hosted payload manufacturer is responsible for the design and manufacture of hosted payload and shall therefore warranty the hosted payload in accordance with negotiated terms. Such terms may include a requirement for company to carry insurance (e.g., launch and one year of operations) for the hosted payload. The company is generally required to compensate government in the case of an insurance claim in accordance with negotiated terms of the "Failure to Perform" clause of the contract.

3.5.3. Other Issues

Export control, as governed by the International Traffic in Arms Regulations (ITAR) in the United States, plays a major role in any satellite program. Flying a payload for a U.S. Government agency on a commercial satellite can introduce a number of export control and other policy issues, including the ability to use a foreign launcher or satellite integrator, flying a payload that contains foreign components, and flying a U.S. Government payload on a satellite that is also hosting other non-U.S. payloads. These policy issues are currently in flux as the Administration conducts a review of export control regulations and plans potential reforms, so these issues will need to be addressed on a case-by-case basis until formal guidelines are established.

Other issues that the hosted payload operator, satellite operator, and other parties should address during the development of the contract that are specific to each individual mission include:

- Standards for radiation and other hardening of the hosted payload
- Design life of the hosted payload versus the host satellite
- Obligation of satellite operator to share ephemeris and other data with host owner on a routine basis and/or during emergencies
- Requirements for insurance of the hosted payload
- Provision for a spare hosted payload

4. PAYLOAD INTEGRATION AND PRE-LAUNCH ACTIVITIES

This section guides the hosted payload owner on the preliminary stages of satellite manufacturing, including a range of pre-launch activities for commercial satellites.

4.1. CLEAN ROOM REQUIREMENTS

Regardless of whether the hosted payload is assembled alongside the primary spacecraft or whether it is assembled at a separate location and then shipped to the primary spacecraft assembly facility, clean room requirements are usually standardized and do not differ. The primary spacecraft designer and manufacturer determine cleanliness standards and supply them to the hosted payload owners. Should a hosted payload require higher cleanliness standards than the primary, this would have to be settled and arrangement made to the satisfaction of primary and hosted payload operators well before construction commences.

4.2. SOFTWARE REQUIREMENTS

The primary spacecraft sets the standards for pointing accuracy, timing accuracy, attitude stability, and signal interference by which the hosted payload must abide. Any specific requirements for pointing accuracy and timing accuracy should be negotiated between the hosted payload operator and the primary satellite owner and/or manufacturer before contract signature. The difference between pointing knowledge and pointing stability must be clearly defined, as well as the minimum time periods over which this stability must be maintained. Also, as the spacecraft carries a limited supply of maneuvering fuel intended to support the spacecraft's primary payload, hosted payloads should not plan on using this to meet mission requirements unless previously negotiated. Of course, circumstances could arise under which the hosted payload owner compensates the primary operator for any required maneuvers and the resultant shortening of the primary spacecraft's useful lifespan. This extra cost could be absorbed by hosted payload owner to compensate for the lower costs of flying an instrument as a hosted payload rather than on a dedicated platform.

4.3. SATELLITE TEST ACTIVITIES

Because of the rapid manufacturing timelines for commercial spacecraft, satellite manufacturers often utilize parallel assembly of different spacecraft subsystems (the core structure, power management systems, payloads, etc.) to speed up the construction process. Manufacturing subsystems separately requires extensive testing of systems once they've been integrated in order to resolve any power mismatches or interference. Typically, these subsystems are integrated first via wiring and other harnesses, in order to resolve potential problems before the pieces have actually been physically assembled. Ideally, the hosted payload should be ready in time to be integrated and tested alongside other sub-systems of the primary spacecraft. Specific testing requirements and their schedules will vary by manufacturer and even on a satellite-by-satellite basis; those requirements, and the schedule for testing, should be discussed and agreed upon prior to contract signature.

In the event that the hosted payload cannot be tested alongside the primary spacecraft subsystems, there are alternatives available during preliminary testing stages. One method is to assemble a boilerplate mockup of the primary payload, so that the hosted payload can be tested for fit, vibration resistance, and signal interference. However, once past preliminary testing, it is absolutely essential that the hosted payload be ready and available for assembly and integration with the rest of the primary spacecraft. Use of standardized interfaces and payloads that fit within standard ICD constraints greatly increases the probability that late hardware can be accommodated.

It is important that prior to launch the hosted payload undergo dynamic, vibration, and shock testing at a level greater than that expected during launch. This may be a particular concern for any sensors or other sensitive instrumentation that may be part of the hosted payload. If there are any sensors or other devices that are particularly sensitive to the effects of vibration then these should be discussed with the satellite operator during the launch vehicle design phase.

4.4. OVERSIGHT DURING SATELLITE MANUFACTURING

It is customary for the satellite operator to have a presence at the satellite construction premises. This representative participates in the preliminary, critical, and final design reviews; attends weekly or daily briefings; and signs off on the test results on behalf of the satellite operator as part of the acceptance procedure. The type of access this individual (or team) has to the detailed data and schedule is agreed upon beforehand (usually within the contract) and observed throughout the construction schedule.

The hosted payload owner and owner of the primary payload should agree beforehand whether the authority of the former's representative at the construction site should extend to issues concerning the hosted payload. If not, the hosted payload owner should be prepared to negotiate its own presence and access to the test data.

5. LAUNCH AND IN-ORBIT TESTING

5.1. LAUNCH CAMPAIGN

The activities leading to the actual launch are referred to as the launch campaign. They can take several days, and are attended by a team that includes representatives from the satellite owner and the hosted payload owner.

The preparation for launch, including the testing of the primary and hosted payload to verify that no performance degradation has occurred as a result of the transport of the satellite to the launch site, usually takes several days. The actual countdown leading up the launch begins in earnest about 12 hours before the launch window opens.

The countdown includes the following three phases (actual events and timing can vary based on the orbit and the launch vehicle):

- Preparation (around 12 hours to around two hours before launch). All instruments are checked, non-essential personnel are cleared, the launch platform is transported to the launch pad, the hazardous gas detection tests take place and the liquid hydrogen and oxygen systems are being prepared.

- Tanking (around 2 hours to around 5 minutes before launch). During this phase, the main activities revolve around the preparation and loading of the liquid oxygen and hydrogen into the tanks. Temperatures and internal pressures are verified. Weather briefings are held.
- Actual launch (around 5 minutes to liftoff). This phase starts when the fuel fill sequence is complete. The satellite transfers to internal power. The launch control system is enabled and the first stage is ignited. Liftoff follows.

5.2. COMMERCIAL PAYLOAD IN-ORBIT TESTING

Following successful launch of a satellite, in-orbit tests of the communications payload and other satellite subsystems will be conducted to verify that the satellite is fully functional following the stresses of the launch. A large commercial satellite operator may lead the testing with the assistance of the satellite manufacturer. Alternatively, the contractual agreement between the commercial satellite operator and the satellite manufacturer may specify that the satellite manufacturer conduct the tests with the operator witnessing them, and that ownership of the satellite only passes upon successful test completion. The duration of the in-obit testing may be as short as a couple of days to as long as several weeks.

The in-orbit testing will verify that all systems of the commercial payload and spacecraft bus are functional. However, there is always a small probability of degradation or failure of a subsystem or component that is of interest to the hosted payload owner. These would include any loss of capacity of the electrical power bus (including batteries and solar cells), loss of redundancy of a critical subsystem such as the main computer or Attitude Determination and Control Equipment (ADCE), loss of capacity of the thruster or propulsion subsystems, and so on. In addition, based on the actual launch trajectory and the orbit parameters achieved, the satellite operator will also be able to predict an end-of-life date of the newly launched satellite.

The operational agreement should require that the commercial satellite operator provide a report of the in-obit tests of the commercial satellite noting any degradation or loss of redundancy that has the potential to impact the hosted payload missions including a projected satellite end-of-life. In the event that there are any such anomalies then a mitigation plan should be jointly developed.

5.3. HOSTED PAYLOAD IN-ORBIT TESTING

In all likelihood, in-orbit tests will need to be conducted on the hosted payload, for which a detailed plan should be prepared in advance. This plan must specify the role of the hosted payload owner and the hosted payload manufacturer together with the role, if any, of the satellite operator and the satellite manufacturer. In addition to the tests to be conducted on the hosted payload, the plan must address logistical issues related to the orbital location and ground network systems to be used for in-orbit testing.

During the in-orbit testing it is important to test as much functionality of the payload as possible. This should include configurations during normal operations, redundant systems, redundancy switchover, sensitivity of all sensors, physical deployment of any mechanical subsystems, and control/orientation of sensors. The test results should be compared with the pre-launch tests results and any significant changes should be investigated and documented.

5.3.1. Vibration Survival and Other Special Requirements

During launch, satellites are subjected to significant vibration, shock, and acoustic fields generated by the launch vehicle's engines, with the largest shocks occurring on separation of the vehicle stages from the satellite payload. As noted earlier, pre-launch testing will likely exceed the impact of the actual launch, thus any impact on particularly sensitive payload components should have been evaluated and resolved at that time.

With negotiated placement of accelerometers or shock sensors, the satellite operator and launch vehicle manufacturer may be able to measure and record the vibration levels during different phases of the actual launch and compare this to the projected levels. This information should be shared with the hosted payload owner and payload manufacturer to ensure that it is below the maximum vibration levels that the payload can survive. Any data that indicates that excessive vibration was encountered will be a cause for concern. In addition, any other anomalies during the launch that have the potential of affecting the hosted payload should also be communicated.

During in-orbit testing of the hosted payload, special emphasis should be placed on testing those sensors or instrumentation that may be affected by vibration. It will be important to clearly spell out to the commercial satellite operator any additional tests that may require the satellite to be re-orientated on its axis or have adjustments in its position. For example, there may be antennas or sensors onboard the hosted payload for which antenna patterns or sensitivity measurements are required for different azimuth and elevation offsets. Such measurements may have to be made by re-orientating the satellite to simulate the azimuth and elevation offsets, which in turn require carefully controlled commanding and operation by the satellite operator.

For sensitive instruments and other specialized payloads and sensors there may be environmental or other concerns that determine how they will be turned on and deployed. An example of this would be the need for the satellite to complete de-gassing before deploying some sensors. These needs must be communicated in advance to the satellite operator and the protocol that should be followed must be clearly documented and followed.

5.3.2. Orbital Location for In-Orbit Testing

In many cases, the newly-launched satellite will be replacing an existing commercial satellite that is already carrying services. To avoid disruption to these services the satellite operator will conduct the in-orbit tests by temporarily positioning the satellite at a different orbital location. In fact, the launch trajectory will be designed to place the satellite at this temporary test orbital location. After the in-orbit tests have been successfully conducted the satellite will be drifted to its in-service orbital location, which can take several days to weeks. The operational agreement between the commercial satellite owner and the hosted payload owner should specify the orbital location from which in-orbit testing will take place and to the extent possible the hosted payload owner should ensure that this location is visible to the ground network systems of the hosted payload, where relevant.

A key consideration for the hosted payload owner will be to decide whether to conduct the in-orbit tests at the in-service or at the test orbital location. If the payload is totally autonomous from the communication payload and the tests will not in any way impact or interfere with commercial services then it may be possible to test from the in-service orbital location while the new satellite is carrying commercial services. This can only be done if all necessary commanding, measurements, transmissions, and data collection for the tests do not interfere in any way with operational services and the satellite operator will need to agree to this in advance. The advantage of conducting hosted payload testing from such a location is that the ground segment systems are already available and need not to be duplicated. Additionally, tests can be conducted at their own pace without any schedule pressure from the commercial operator.

If the hosted payload in-orbit tests cannot be conducted without impact or interference to commercial services, then they will have to be conducted from the test orbital location. Ideally it may be possible to conduct the hosted payload in-orbit test in parallel with the testing of the communications payload so as to shorten the overall test time. If this cannot be done and the hosted payload testing has to be done sequentially, then there will be schedule pressures from the satellite operator. If the hosted payload in-orbit tests reveal an anomaly that requires further testing or investigation, then the agreement should allow for the satellite to be kept at the test location for an additional period. However, the commercial satellite operator may not be fully amenable to this. In-orbit calibration may require pointing imagers into deep space and require significant spacecraft slewing. This should be conducted well before the spacecraft reaches its operational longitude. Some testing may even be possible during the drift from the in-orbit testing to operational location.

5.4. GROUND NETWORK FOR HOSTED PAYLOAD IN-ORBIT TESTING

Although the in-orbit testing phase of the hosted payload will be of a relatively short duration and will only take place once, careful consideration must be given to the ground network systems that will be used and their location relative to the test orbital location. These systems may include both the operational ground network systems and any additional specialized subsystems and software identified with the manufacturer of the hosted payload specifically for in-orbit testing.

Under the ideal scenario, testing will be conducted from the in-service orbital location using as much of the ground network systems used for the operational phase as possible. If testing from the in-service orbital location is not feasible, then arrangements for the needed ground network systems accessible from the test orbital location must be made. If the hosted payload uses different frequency bands from the communications payload, then it will not be possible to use the same antennas for in-orbit testing that are being used by the satellite operator.

If the ground antennas used for the normal operations phase can see the test orbital location then it will simply be necessary to re-point these antennas. If these antennas cannot see the in-orbit test location then it will be necessary to either duplicate or temporarily relocate ground network systems to such a location.

Another option would be to discuss with the commercial satellite operator the possibility of temporarily parking the satellite after the communication payload in-orbit testing to another test orbital location that is visible to the hosted payload ground network system. The commercial satellite operator may be reluctant to do so since this would expend propellant to stop/start the drift to this location (thus shortening the satellite end of life date) and also delay the in-service date of the commercial payload.

5.5. HOSTED PAYLOAD DEPLOYMENT AND ACTIVATION

After in-orbit tests have been completed, the satellite will be drifted from the test location to the in-service orbital location. During this drift, the hosted payload should be configured in a manner that ensures its integrity. A faster drift rate means that the satellite will arrive sooner at the in-service location, but more propellant will be used, which shortens the satellite end-of-life. The drift time, which may be a few days or a few weeks, will be determined by the satellite operator, taking these factors into consideration.

During the drift the satellite will pass other satellites positioned in the geostationary arc and the satellite operator will ensure that such passes are coordinated with other satellite operators as necessary and that the appropriate satellite beacons are turned on or off. Once the satellite approaches the in-service locations a stop maneuver will be done and the satellite positioned correctly. If the new satellite is replacing an existing one, the satellite operator will then transition services from the old satellite to the new satellite by turning off and turning on the communications payloads in a coordinated manner that minimizes disruption to existing services. The old satellite will then be moved from this location either to a different location or if it is at the end-of-life it will be de-orbited. After this the hosted payload owner will be in a position to deploy, configure, and activate the payload and commence the mission and enter the operational phase.

6. OPERATIONAL PHASE AND END OF LIFE ACTIVITIES

6.1. INTRODUCTION

This section guides the hosted payload owner on the operational phase of the commercial satellite during both normal and abnormal situations. Abnormal situations may arise when there is a technical or operational issue with the hosted payload, or with the commercial payload, or even when there is an abnormal situation elsewhere on the satellite operator's network. It is even conceivable that an abnormal situation arises because of changing needs of a customer that presents a large and unexpected commercial opportunity for the satellite operator.

The operational and commercial needs of the satellite operator may at times be different and in conflict with those of the hosted payload owner. Such conflicts present potential risks to the payload owner that must be understood, addressed, and mitigated in the operational agreement. The degree of protection sought by the hosted payload owner against such risks will impact the cost and willingness of the commercial operator to host the payload. Since it is not possible to envisage in advance all possible scenarios, the operational agreement must also have a mechanism for consultation in the event that a situation arises which has not been detailed in the operational agreement.

6.2. NORMAL OPERATIONS OF HOSTED PAYLOAD

The hosted payload owner will need to spell out the role and requirements of the satellite operator during normal operations of the hosted payload. The degree of this role depends upon whether the hosted payload is fully autonomous or is integrated with the commercial satellite payload. As a minimum the hosted payload will only require electrical power from the commercial satellite while at the other extreme telemetry, commanding and data collection of the hosted payload may be fully integrated with the commercial payload. Heat dissipation from the payload to the spacecraft would be handled on a case-by-cas basis based on the specific configuration of the hosted payload, the primary payload, and the host spacecraft.

6.2.1. Hosted Payload Reconfiguration

In normal day-to-day operations the extent to which the hosted payload is reconfigured will depend upon how static or dynamic the payload mission is. On some missions there is an initial configuration of the hosted payload and, after that, there is data collection for a substantial period of time without any changes. Other missions may require frequent reconfigurations or redeployment of various sensors on a dynamic basis, in certain cases with little lead times. The role if any of the commercial satellite operator in such reconfigurations must be laid out in a clearly defined protocol and procedure. Note that satellite operators will not send any command sequences to the spacecraft to reconfigure the hosted payload without prior scripting and validation. This assures safety of both the host spacecraft and the hosted payload.

6.2.2. Ground Network Operations

Another factor is the design and operation of the ground network used for commanding and controlling the hosted payload and for data collection and transfer. The ground network may be totally separate from, may share some elements with, or may be fully integrated with the commercial payload ground network. If the commercial satellite operator is providing part or all of the ground network, then the required reliability and the services required must be defined in a Service Level Agreement (SLA) including local storage of any hosted payload data for subsequent transfer.

6.2.3. Security of Operations

Depending upon the nature and sensitivity of the mission of the hosted payload there may be security safeguards and procedures that must be followed by the commercial satellite operator. These procedures may include restrictions on the nature of any public communications by the commercial satellite operator during the lifetime of the hosted payload. In terms of operations a security regime may need to be outlined that defines the security procedures that must be followed during the operational phase, including protection of data and security clearance of any personnel involved in the operating the hosted payload. Release of information to the public regarding possible on-orbit anomalies of either the host spacecraft or the hosted payload needs to be thoroughly coordinated due to the potential legal implications.

6.2.4. Black-out Periods

There may be times when the hosted payload is in a critical phase of its mission and it is desirable to minimize any risks or perturbations to the hosted payload and the associated ground network. During such times it may be desirable that the commercial satellite operator minimize any operations that could have the potential to disrupt the payload or the data collection. An example would be avoidance of any maintenance on the ground network or avoidance of any commanding or reconfiguration of the commercial satellite payload. This can be achieved through a request by the hosted payload owner for a black-out period of a relatively short duration and can be outlined in a standard operating procedure. Black-out periods may also include times when bus operations are "quieted" by suspending normal activities that could induce attitude instabilities (e.g., thruster firing, mechanism stepping)

6.2.5. Routine Tests on Hosted Payload

Periodically, there may be a need to conduct routine tests on the hosted payload. These may be required, for example, to test any redundant systems, or to check degradation of any on-line systems or sensors. Depending upon the level of integration of the hosted payload with the commercial satellite, such testing may require participation by the commercial satellite operator. Again the nature, timing, and frequency of such tests will require an agreement in advance. In general, after the spacecraft is put into commercial service, off-pointing of the bus (i.e. for instrument calibration) will not be permissible.

6.3. NORMAL OPERATIONS OF COMMERCIAL PAYLOAD

6.3.1. Communication Payload Reconfigurations & Routine Testing

During normal operations, the commercial payload of some satellites stay very static while on others there may be a significant amount of reconfiguration of transponders, beams, gain settings, and other parameters, depending upon customer needs. Such changes will not impact the hosted payload during normal operations and normally the commercial operator will not be under any obligation to notify the hosted payload owner of this either in advance or after it is completed.

The satellite owner may also conduct routine testing on the commercial payload during normal operations. Usually the purpose of such testing is to measure transponder characteristics, either to see if there is any degradation or to demonstrate certain characteristics to an existing or potential customer. Again, such activity will not impact the hosted payload and the commercial operator will not be obliged to advise the hosted payload owner in advance.

6.3.2. Operations During Eclipse Seasons

During eclipse seasons—the periods around the spring and fall equinoxes when GEO satellites can spend as long as 70 minutes per day in the Earth's shadow—the commercial operator may invoke some special procedures such as shutting down some non-critical components to conserve power or for thermal stability. These procedures are generally transparent to all customers. The only times this may be of interest to the hosted payload owner is if there has been an anomaly on the satellite that affects the electrical and battery power capacity of the satellite, which in turn necessitates some additional power conservation steps by the commercial satellite operator during the eclipse season. Any possible impact of this on the hosted payload owner would be communicated well in advance.

6.3.3. Regular Satellite Status Reports and Customer Meetings

Some commercial satellite operators issues periodic reports—annually or more frequently—for their customers on the health and operational status of the satellite. These reports will generally comment on the redundancy status of the critical subsystems and on the electrical power, solar cells, and battery, as well as the expected satellite lifetime. If the hosted payload owner requires any additional reports beyond these then it will be necessary to spell these out in the operational agreement. Similarly, commercial operators hold periodic meetings for their commercial customers which should also be open to the hosted payload owner if desired.

6.3.4. Normal Satellite Station-Keeping

The commercial satellite operator will control the location of the satellite through station-keeping to remain within a pre-defined east/west and north/south box which is generally plus/minus 0.05 degrees in each direction. However, there may be rare times when the operator will allow the satellite to drift outside this box. Generally such situations will be closely coordinated with customers to mitigate any impact. Towards the end of the satellite life, the operator may decide to allow inclined operation of the satellite by curtailing north/south station-keeping and allowing the inclination to grow at up to 0.8 degrees per year. Unless there is an abnormality, such activities occur towards the end of life of the satellite and any impact on customers is discussed well in advance.

6.4. ABNORMALITIES ON HOSTED PAYLOAD

The level of integration of the hosted payload with the telemetry and commanding of the commercial payload will dictate the role, if any, of the commercial operator in any hosted payload abnormality. If the hosted payload has a totally separate telemetry and command subsystem, the commercial operator will in all likelihood have little or no role in any testing, diagnosing, reconfiguring, or other such activity in the hosted payload.

If, on the other hand, the telemetry is integrated then the roles and responsibilities of the satellite operator, the hosted payload owner, and the technical support from both the satellite manufacturer and the payload manufacturer will need to be understood and perhaps detailed in terms of a service level agreement with appropriate response times and levels of resources made available.

The satellite operator will need to be assured that any failure or abnormality of the hosted payload does not in any way jeopardize the future safety or integrity of the satellite. Examples of such abnormalities may be an excessive power drain or a thermal imbalance situation. To this end there may be an obligation to share detailed data on the failure/abnormality.

6.5. ABNORMALITIES WITH THE COMMERCIAL PAYLOAD AND COMMON SUBSYSTEMS

6.5.1. Temporary Satellite Abnormalities

Commercial satellites encounter abnormalities from time to time, the vast majority of which are generally short term and are corrected by switching to redundant systems, reconfiguring, or through re-commanding. The extent to which the abnormality affects the hosted payload will depend upon whether the abnormality affects a common system and whether it is temporary or permanent in nature. An example of a temporary abnormality is loss of earth lock by the satellite resulting in temporary loss of all services.

During an abnormality event, the commercial operator’s first priority is the safety and protection of the satellite and, to this end, it will do what is deemed necessary even at the temporary expense of its service to commercial and hosted payload customers. If the abnormality causes a service disruption then the commercial operator will generally consult with customers through conference calls and emails. Once the abnormality has been corrected or mitigated, the commercial operator will conduct a thorough review, which may take weeks or even months, and provide a status report to customers. The satellite operator is generally not as forthcoming as customers may want in the explanation of the event and its possible future impact. Since public statements regarding on-orbit anomalies can severely impact corporate financials, release of non-verified information, which later proves to be incorrect, can lead to future legal action.

6.5.2. Permanent Redundancy Loss

Some satellite abnormalities may result in permanent degradation or loss of redundancy of critical subsystems. Examples of such abnormalities include:

- A permanent loss in solar cell capacity resulting in loss of bus power
- A permanent degradation of the battery impacting eclipse seasons
- A permanent failure of a critical subsystem with loss of redundancy
- Mis-operation during a station-keeping maneuver with loss of propellant

In some situations permanent loss of redundancy may cause significant concern on the part of the commercial customers on the satellite. In order to appease such customers, the satellite operator may desire to replace the satellite with an in-orbit spare and thus move the satellite with the hosted payload to another orbital location. The operational agreement with the satellite operator must spell out the acceptability of moving the satellite to another orbital location and the range of orbital locations that are acceptable. The operational agreement should also specify a process for consultation before such a move and any compensation to the hosted payload owner including possible termination of the hosting. In general, the satellite owner will not make any guarantees outside of the range of the contractual commitment by the hosted payload owner.

Where there is the loss of redundancy in a critical subsystem such as the main computer or the ADCE, the satellite is one subsystem failure away from total loss. In such cases the satellite operator will attempt to develop work-around and contingency plans and will consult closely with customers who may be impacted. The hosted payload owner may wish to look at the possibility of accelerating the mission of the payload or re-prioritizing activities to ensure that as much of the payload mission can be achieved as quickly as possible.

6.5.3. Degradation of Critical Subsystems

There may be instances where there is a degradation of a critical subsystem without outright loss of redundancy. This can occur when there is an unexplained anomaly on the satellite that is believed to be caused by the on-line unit (say “A”). The commercial satellite operator may then either continue to operate with unit “A” or put unit “B” online. Unit “A” will then be treated to be in degraded mode and additional tests may be conducted to further clarify its status.

In certain situations the commercial satellite operator may seek some concessions from customers in case of degradation in the capability of the satellite. For example, if there is degradation in the power bus capacity then the satellite operator may wish to reduce the electrical power load on the bus by turning off some subsystems (especially during the eclipse season). The satellite operator may then consult with the hosted payload owner to see if there is any flexibility in this. In return for this the hosted payload owner may be able to negotiate some financial or operational concessions.

6.6. NON-ROUTINE OPERATIONAL SITUATIONS WITH POSSIBLE IMPACT ON HOSTED PAYLOAD

There may be situations in which the commercial satellite operator chooses to make operational changes affecting the payload even when there is no anomaly with the hosting satellite. Such situations may arise because of an anomaly or failure of another satellite owned by the operator and the need to restore the services on that other satellite. Even if there is no such anomaly then there may be commercial pressures because of the opportunity cost of a large new customer requirement. Examples of such situations include:

- The contractual obligation of the satellite operator to restore certain customer services in the event of other capacity on the operators network.
- The total failure another satellite and the possibility of the satellite moving the hosted payload satellite to another orbital location.
- The desire of the satellite operator to move the hosted payload satellite to another orbital location so as to improve the fill factor (i.e. revenue).

As part of the pre-contract negotiations, the hosted payload owner must fully understand the range of such situations that may arise during the operational lifetime of the satellite and the hosted payload. The operational agreement must layout the bounds of what the satellite operator is or is not permitted to do and specify the range of orbital locations that are acceptable. The degree to which the satellite operator’s flexibility is constrained will impact the willingness and cost of hosting the payload on the satellite. The operational agreement should also specify a process for consultation before such a move and any compensation to the hosted payload owner including possible termination of the hosting.

6.7. END-OF-LIFE ACTIVITIES

6.7.1. Hosted Payload Life

The operational agreement with the satellite operator will specify the period that the payload must be hosted and operated in-orbit. This period may be different from the lifetime of the satellite and thus when the hosted period has ended, the commercial satellite operator will be free to redeploy the satellite to another orbital location. During the operations phase, the hosted payload owner may wish to either extend or possibly shorten the hosting period. The operations agreement could allow a mechanism to do so, including any reduction or increase in hosting cost.

Following the end of the agreed period, the satellite operator will want to ensure that the payload is terminated in a manner that assures the future integrity and safety of the satellite. This is particularly important when the commercial payload is not being decommissioned but will continue to provide service to other commercial customers.

The hosted payload owner may wish to keep the payload in a dormant state if desired and possible, in which case this must be agreed to by the satellite operator. It may be possible to continue to collect data on the health and status of the hosted payload for lifetime reliability statistics. If the hosted payload owner wishes to deny use of the hosted payload to the satellite owner after end of the hosting contract, this should be clearly defined in the hosting contract.

6.7.2. Decommissioning of Satellite

Normally the commercial satellite operator will decommission the satellite at the end of its "useful life". The useful life may be different from the original design life and there must be enough propellant fuel to de-orbit. It will also depend upon the availability of the follow-on satellite for that location. If, for example, availability of the follow-on or replacement satellite is delayed, then the operator will take necessary steps to extend the satellite life including possibly introducing inclined orbit operation. Eventually, when the satellite is decommissioned it will be disposed of by using remaining fuel of the thrusters to lower and de-orbit the satellite (for LEO) or raise the orbit (for GEO).

One possibility that the hosted payload owner may need to be aware of is sale of the satellite or the entire operator. While the satellite may not be decommissioned in this scenario, it may impact the hosted payload owner and is an eventuality to be covered in the contract, since the new owner may choose to move the satellite to a different location.

7. ACKNOWLEDGEMENT

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APPENDIX: CONTACT LISTS

The following are key individuals at major commercial satellite manufacturers and operators who are involved in hosted payload programs at their companies, as of August 2010.

Table 5: Satellite Operator Contacts

Name	Organization	Email
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