Leveraging Commercial Communication Satellites to support the Space Situational Awareness Mission Area

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ABSTRACT

The majority of USSTRATCOM detect and track requirements in the geosynchronous regime could be met via strategic placement of medium grade optical sensors on select geosynchronous satellites at relatively low cost in less than 48 months. An architecture which includes hosting SSA sensors on eight to ten commercial communication satellites could provide for highly accurate, timely and relatively inexpensive detect and track capabilities. The major factors considered when hosting any sensor on a commercial communications satellite are size, weight (mass) and power or SWAP. Additional sensor specific items must also be considered to form a complete feasibility analysis. These include data rate, mounting constraints, thermal balance, timing accuracy, and attitude stability requirements. All of these factors directly impact the cost and flexibility of hosting such a sensor on a geosynchronous communication satellite. By choosing a relatively light weight, low power consumption sensor which requires a small amount of bandwidth to transmit its data, the cost of hosting the sensor is kept to a minimum. Once the type of sensor or sensors is identified, the next step is to identify idea geosynchronous locations for the "hosted" sensors. Once these locations are identified, then one would identify a potential host which needs to be replaced within the desired timeframe. Once the host is identified, then the satellite owner / operator should be approached about hosting a "neighborhood" watch sensor aboard their spacecraft. Commercial satellites are routinely replaced based on age, lack of available station keeping fuel or to allow a service provider to upgrade its capabilities. Each commercial communication satellite operator maintains a plan of replacing spacecraft. Between the two largest commercial SATCOM providers, INTELSAT and SES, six to eight spacecraft will be replaced each year (100 plus spacecraft with 15 year average lifetimes). The satellites are usually procured, designed, built, launched and operational within 36 months. In order for the US Government to adapt to this timeline, a sensor specification would need to be established as well as a sensor procurement pipeline. The sensors would then be provided to the satellite bus manufacturer for integration onto the bus. The spacecraft would then be launched and operated by the commercial SATCOM operator for the life of the spacecraft.

Based on this approach, it is highly conceivable that a complete geosynchronous "neighborhood" watch program could be completed within 48 months of initiation.

1. BACKGROUND

Improving Space Situational Awareness (SSA) continues to be a high priority within the Department of Defense with increasing interest and support of the US Congress. There is also a growing concern among space system owners and operators as to what is really out there, where is it, and where is it going. The number of objects in the geosynchronous orbit (GEO) continues to increase. Without more precise knowledge of where the objects are and better coordination between operators, it is likely that we will have another accidental collision in space as previously occurred between the French satellite Cerise and an Ariane rocket body in 1996. The Air Force's SSA capability needs to recognize the importance of improving the ability to detect and track smaller objects at or near GEO orbits more accurately and quickly than ever before. Many of the current space control architectures within the Air Force and the Department of Defense recognize that in order to address this need, some set of sensors must be placed in geosynchronous orbit itself.

An architecture, which includes hosting SSA sensors on commercial communication satellites could provide for highly accurate, rapid and relatively inexpensive detect and track capabilities at GEO. A study by Dr. John Beusch's MIT Lincoln Laboratory team was presented at the 2008 Space Control Conference which provides the technical underpinnings for such an architecture. This study concludes that close to 100% of the GEO belt can be monitored with no more than ten sensors. [1] This paper expands on the concept and provides details on how these sensors can be incorporated into the perspective commercial communication satellite operators' strategic planning processes.

2. SENSOR CONSIDERATIONS

In considering hosting SSA sensors on commercial communication satellites there is one important question that must be answered; what size of object do I want to be able to detect and track and how far away do I want to be able to detect that object. Why is this question so important in this architecture? The ability of the sensor to see objects that are small or have a low geometric albedo is directly related to sensor complexity and size and therefore sensor mass A sensor that can see smaller objects, further away can satisfy more of the desired SSA mission requirements. As the size, weight (mass) and power (SWAP) of the sensor increase, so do the costs related to hosting the sensor on a commercial communication satellite. The SWAP also directly impacts the available host spacecraft opportunities. If the sensor becomes too large or draws too much power, the result may be that it simply will not fit on a prospective host without great cost. Therefore a balance must be found between the desired capability of the sensor and the contribution of the sensor to the SSA mission. Striving to keep the sensor SWAP within certain boundaries will keep costs reasonable and maximize the hosting opportunities.

Early proposals from the commercial satellite communication industry to host star sensors onboard their satellites were deemed to be insufficient in meeting desired capability needs. The use of star sensors are attractive to the host spacecraft operators because they are relatively inexpensive, very light and do not consume much power. However, their contribution to the SSA mission is also very limited and the benefits do not justify the associated costs. According the MIT Lincoln Lab study a mid-sized sensor in the 100 Kg range would provide an ability to detect and track microsatellite sized objects at distances great enough to provide meaningful and useful data to meet the US STRATCOM capability needs. [1] The MIT study goes on to show that with SSA sensors hosted on as few as eight to ten spacecraft, you could monitor nearly 100% of the GEO belt continuously. A sensor any larger than this "mid-sized" sensor may be able to provide additional capabilities but the cost curve quickly increases and the hosted payload concept quickly loses its appeal.

In addition to the sensor SWAP, other characteristics will influence the cost and desirability to host the sensor on a commercial SATCOM host. All sensors will need to transmit their collected data to a ground processing system. The great thing about hosting a sensor on a SATCOM satellite is that the data can easily be transmitted back to earth. The sensor owner could simply pay for the use of the bandwidth they would use to transmit this data. If all the data was sent to the ground, data rates are higher, but the complexity of the sensor is lower. If computing capability to process the data onboard is included in the sensor and only processed "streak" data is returned to the earth, the data rates are cheaper, but the complexity of the sensor is increased. This is another area where trades can take place to find the balance between costs of data transmission versus the cost of complexity in the sensor.

An SSA sensor would need to be able to see objects in the GEO belt within its field-of-view (FOV). Therefore the sensor would have to be mounted in an area where it could have a clear FOV of the GEO belt and not interfere with the commercial mission of the host spacecraft. This would generally result in the sensor being placed on a boom tower away from the spacecraft and behind communication antennas pointed towards the earth. Other items including sun-inclusion, thruster plume, and jitter effects will help determine what type of sensor technology to use and where the sensor would have to be placed.

An oft forgotten difficult design parameter for integration of payloads onto a host spacecraft is thermal balance constraints. Larger sensors would more than likely require more heat rejection, if the sensor cannot reject its own heat into space, then the host spacecraft must provide additional heat rejection. Thermal balance can almost always be achieved on a spacecraft, however it comes at a price: mass, schedule and usually cost. Ensuring the design parameters are well understood ahead of time, greatly aids in achieving the balance required.

Commercial communication satellites do not require a great deal of timing or pointing accuracy when compared to satellites that normally host highly accurate sensors. If the spacecraft time is accurate within a few seconds, it is accurate enough. Timing accuracy for SSA sensor data will require a much more accurate timing source. This timing source will either have to be incorporated into the sensor or it would have to be an added requirement for the host spacecraft. Adding a GPS timing source to the host spacecraft would add costs, but one that is reasonable. Similarly, SATCOM satellites do not have a very “tight” requirement for stability or pointing accuracy. The pointing accuracy requirement for a SATCOM is driven by the need to maintain antenna patterns on the surface of the earth. If the pointing of the spacecraft is maintained within 0.1 degrees, the spacecraft maintains the operators’ requirements. This accuracy is easily maintained with earth sensors and a standard attitude control system. Another by-product of the pointing accuracy required for commercial communication satellite is a higher tolerance of jitter as compared to normal high-accuracy sensor host satellites. The MIT Lincoln Lab study discusses how a proper sensor design can meet SSA performance requirements without increasing the pointing and jitter control requirements of a standard commercial communications satellite. [1] Designing a sensor that can perform with the standard requirements is key because requiring the host spacecraft to increase its pointing accuracy or decrease its jitter would dramatically increase design complexity and therefore costs..

All the factors mentioned above directly impact the cost and flexibility of hosting such a sensor on a geosynchronous communication satellite. By choosing a relatively light weight, low power consumption sensor which requires a small amount of bandwidth to transmit its data, the cost of hosting the sensor is kept to a minimum.

3. PLANNING TIMELINES

The typical commercial satellite planning and construction program begins about 36 to 48 months before a satellite is due to be replaced. As depicted in Fig. 1, the planning phase is 12 to 18 months in length and then this is followed by a construction and launch phase lasting approximately 24 to 30 months. The optimal time to begin planning hosting sensors on a commercial satellite bus is during the early planning phase.

During this time period the commercial operator is analyzing potential sources of income which will come from operating the spacecraft over its average 15 years of life. This potential income is then compared to the associated costs for acquiring the spacecraft. Based on this information, the projects anticipated financial performance, usually using a metric such as its Internal Rate of Return (IRR) is calculated. If the projected IRR is not greater than the company’s minimum rate of return (typically arrived at by calculating what could be earned by alternate uses of company capital (investing in other projects, buying bonds, etc.) then the project is either modified to increase the IRR or, if that cannot be done, scrapped completely. A typical commercial communication satellite can cost from $250M to $350M including spacecraft, launch, and launch and on-orbit insurance. The commercial models insure that over the average 15 year operational lifetime of the spacecraft that the IRR will meet the investors’ expectations. The optimum planning window for considering hosting payloads is during the Industry / USG Opportunity Analysis period as shown in Fig. 1. This time period is the most flexible period in the planning window. Any earlier than this and the plans for a specific spacecraft are too fluid and contain too much uncertainty to be able to establish any design criteria and orbit location. Any later than this, you end up with whatever is available from the host spacecraft and flexibility is highly constrained.

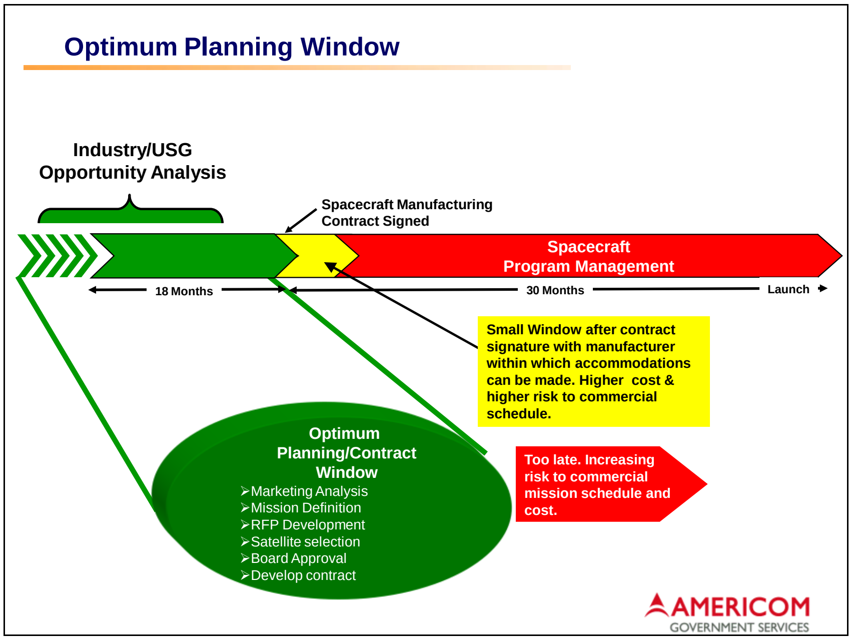

Fig. 1. Optimal planning window for hosted payloads

Discussions with leading sensor builders indicate that their developmental cycle is on the order of 24 months from sensor design through subsystem test and calibration. The design and integration process for a typical satellite construction and launch is illustrated in Fig. 2. The sensor design, build and test can overlap with the spacecraft subsystem design and build, if the sensor design is mature and all interface requirements are known and well documented. These interfaces would include mass, size (to include all control and communications electronics), power, thermal and mounting constraints. If this information is known and incorporated into the design of the host spacecraft, the sensor could actually arrive at the spacecraft manufacture shortly after spacecraft integration begins. Therefore the sensor must be completed approximately 12 to 16 months before the scheduled launch of the host spacecraft. Given these scheduling constraints, the selected SSA sensor would have to be under construction months before its host spacecraft. This type of architecture is achievable if the US Government develops a sensor specification and establishes a sensor procurement pipeline. The sensors would then be provided to the satellite bus manufacturer for integration into the bus at the appropriate time.

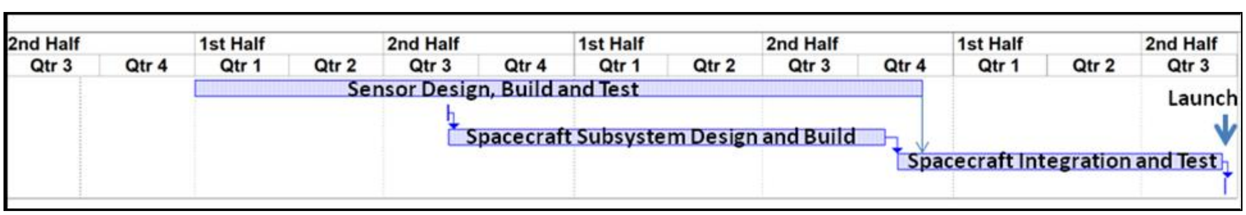

Fig. 2. Typical Commercial SATCOM Spacecraft Design, Build, Integration and Launch Schedule

4. FINDING YOUR RIDE

Commercial satellites are routinely replaced based on age, lack of available station keeping fuel or to allow a service provider to upgrade its capabilities. Each commercial communication satellite operator maintains a plan of replacing spacecraft. The typical communication satellite is designed to last approximately 15 years. The two largest commercial SATCOM providers in the world, SES (SES Americom, SES New Skies and SES ASTRA) and

INTELSAT operate over 100 such spacecraft. It does not take rocket science to calculate that it will take approximately seven spacecraft launches per year to maintain their current fleets.

Even though there are seven launches per year, not every one of these launches is an ideal candidate for hosting an SSA sensor. As discussed earlier in the Introduction, 10 sensors equally spaced around the GEO belt would provide nearly 100% coverage down to the microsat size of object. [1] Referring back to my advanced math for engineers class, I calculated that you would want to host a set of sensors on a GEO spacecraft approximately every 36 degrees. Commercial spacecraft are not spread out evenly around the GEO belt, they tend to be concentrated in higher numbers in areas with high demand and more sparsely spaced in areas of lower demand. Therefore it is possible that two, three or even four consecutive spacecraft would be going to roughly the same area in the GEO belt and only one or two of them would be adequate candidates for hosting an SSA sensor.

Spacecraft that are going to be launched in 2010 or earlier are more than likely already designed and under construction. Based on the optimal planning timeline presented above, hosted SSA plans should begin with satellites that will be launched in 2011 or later. A potential replenishment plan for SES satellites from 2011 to 2014 is presented in Fig. 3. This replenishment plan is based on replacing the SES satellites that were launched from 1996 to 1999. This plan shows that you could select 8 – 10 spacecraft in a four year period which would place a hosted SSA sensor at or near the desired 36 degree spacing. A gap remains around the degree East longitude orbital position. This spot could be filled by extending the desired fielding period or including other service providers replacement plans into the fielding strategy.

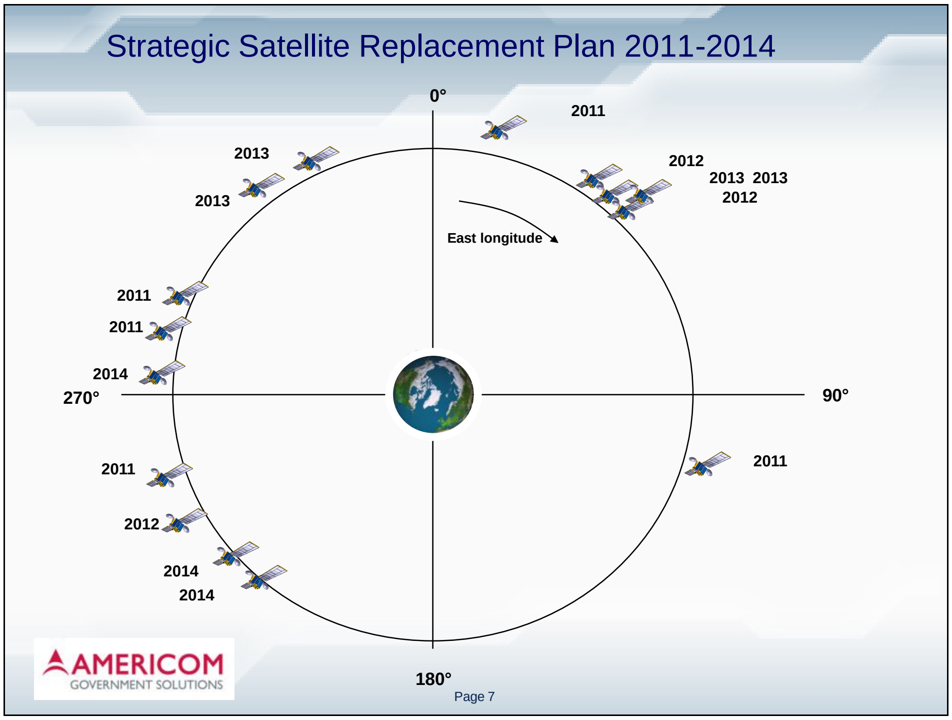

Fig. 3.

5. SUMMARY AND CONCLUSION

Increasing our ability to track objects in space more accurately and timely is growing in importance. This increased need is driven by the increased number of satellites operated in space, in the increase in debris and the technology advances that are producing smaller and smaller satellites. An SSA program aimed at dramatically increasing the detect and track capabilities at GEO could achieve full operational capability within 6 years by leveraging the hosted payload concept. The key to accomplishing this task is to select and define an appropriate sensor in 2009 at the same time begin working with the commercial communication satellite providers in parallel.

6. REFERENCES

1. Dr. John Beusch, MIT Lincoln Laboratory, Onboard SSA Concept for Geosynchronous Object Detection and Tracking. Briefing given to the 2008 Space Control Conference, 29 April 2008.