THE NEED FOR AN INSTRUMENT FIRST, SPACECRAFT SECOND MISSION DEVELOPMENT APPROACH

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1. INTRODUCTION

Developing complex NASA science instruments is a formidable challenge. NASA continually improves its ability to deliver world class science by constantly pushing the start of the art in developing technologically challenging instruments. The inherent difficulty of developing these instruments, however, can lead to development difficulties with associated schedule delays and cost growth. When the other mission elements, including the spacecraft and ground systems, are developed and mature faster than the instrument, a "marching army" cost can be incurred as these other elements wait for the instrument to become ready. This paper discusses the historic difficulties of NASA science instrument development and the associated cost and schedule growth while proposing a potential approach to reduce this growth for future missions.

2. DISCUSSION

Historically, most NASA missions have had instrument development issues [1]. Specific examples of recent problems include the development of the Burst Area Telescope (BAT) instrument on Swift, the Cloud Profiling Radar (CPR) instrument on Cloudsat and the Geoscience Laser Altimeter (GLAS) instrument on ICESAT. Each of these missions resulted in significantly more cost growth to the project than the cost of the instrument growth alone. As can be seen in Figure 1, instrument development difficulties led to delays in instrument delivery which results in significant cost growth in the instrument and the subsequent total mission cost due to the marching army cost. For the examples shown, the ratio of total mission cost growth to instrument cost growth is on the order of 2:1 to 3:1. Although it is understood that other factors contributed to the cost growth of these missions, it is believed that the instrument delivery delays were the primary contributor.

Missions where the majority of instrument issues were resolved prior to the start of spacecraft development, such as QuikSCAT and QuikTOMS, are in sharp contract to these missions. For both of these missions, the instruments for each, SeaWinds for QuikSCAT and TOMS for QuickTOMS, had already been largely developed prior to spacecraft acquisition. Each instrument was able to be integrated with spacecraft and launched in the

relatively short time of two years. Reducing the development time and integration uncertainty of these types of missions can help to keep the cost growth relatively low.

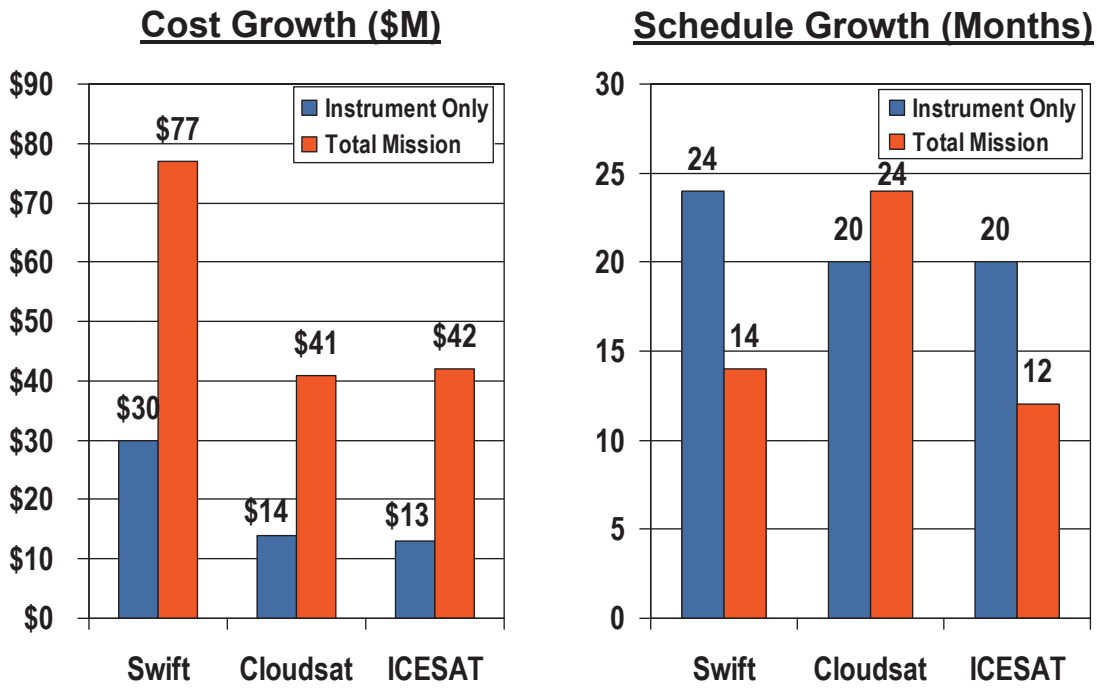

Figure 1: Instrument and Total Mission Cost and Schedule Growth for Missions with Instrument Difficulties

To extend this to a larger data set, a recent investigation of the causes of cost and schedule growth for forty NASA missions indicates that over two-thirds of the missions experienced instrument development difficulties [1]. Figure 2 shows the results of this study where a third of the missions had instrument problems only and another 30% of the missions had both instrument and spacecraft development problems. Figure 3 shows the associated cost growth for these missions where missions that only had instrument development problems experienced over twice the cost and schedule growth of missions that only had spacecraft development problems. It is postulated that cost growth for instrument development problems are more prevalent and have higher cost growth because instruments are the primary, challenging developmental items for NASA science missions while spacecraft have less developmental issues. With the availability of standard spacecraft busses available through NASA's Rapid Spacecraft Development Office (RSDO) and commercial providers, the complexity of instruments relative to spacecraft is even greater for potential, future Earth science missions.

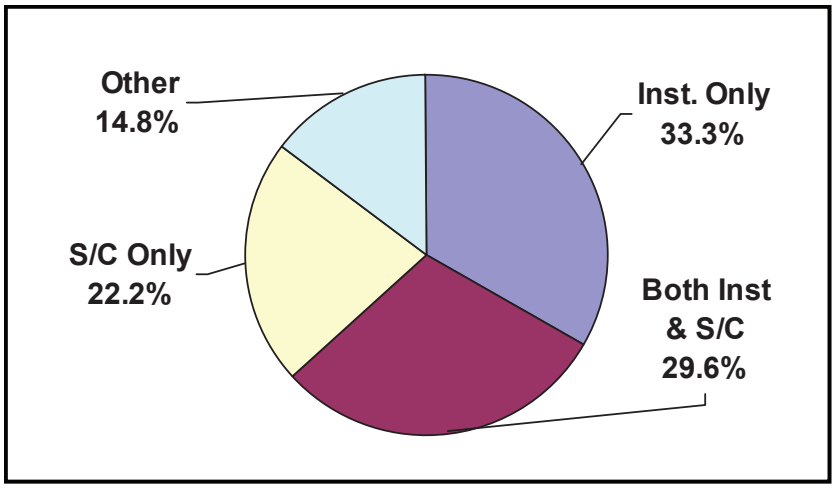

Figure 2: Distribution of Problems Identified for a Forty NASA Mission Set Studied

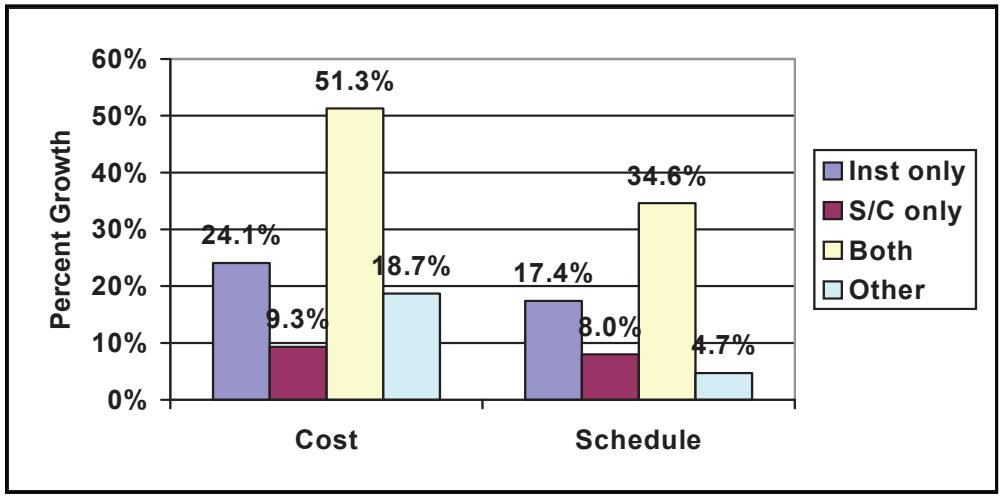

Figure 3: Associated Cost and Schedule Growth as a Function of the Problems Encountered

The difficulty of instrument developments versus spacecraft developments can also be seen while investigating resource growth for historical NASA missions. A more recent study reviewing a subset of twenty NASA missions in greater detail demonstrate that instrument resources such as mass and cost grow at a significantly greater rate than spacecraft resources [2]. Figure 4 shows the average percentage mass and cost growth of the instruments and spacecraft from the start of Phase B within this twenty mission data set and shows that that the growth for instruments is essentially twice the growth of spacecraft. This incongruity implies that instruments typically are less mature than spacecraft at the initiation of a project, as shown by the differences in mass growth, which leads to cost growth thereby supporting the idea of developing instruments prior to the spacecraft in order to minimize the marching army effect of spacecraft waiting for instruments to be delivered. Based on the immaturity of the initial instrument design, the history of instrument development difficulties and the associated

total mission cost growth, an approach that develops the instrument first before the other mission elements, referred to as the instrument first, spacecraft second (IFSS) mission development approach, could potentially provide a reduction in cost growth in the development of NASA missions.

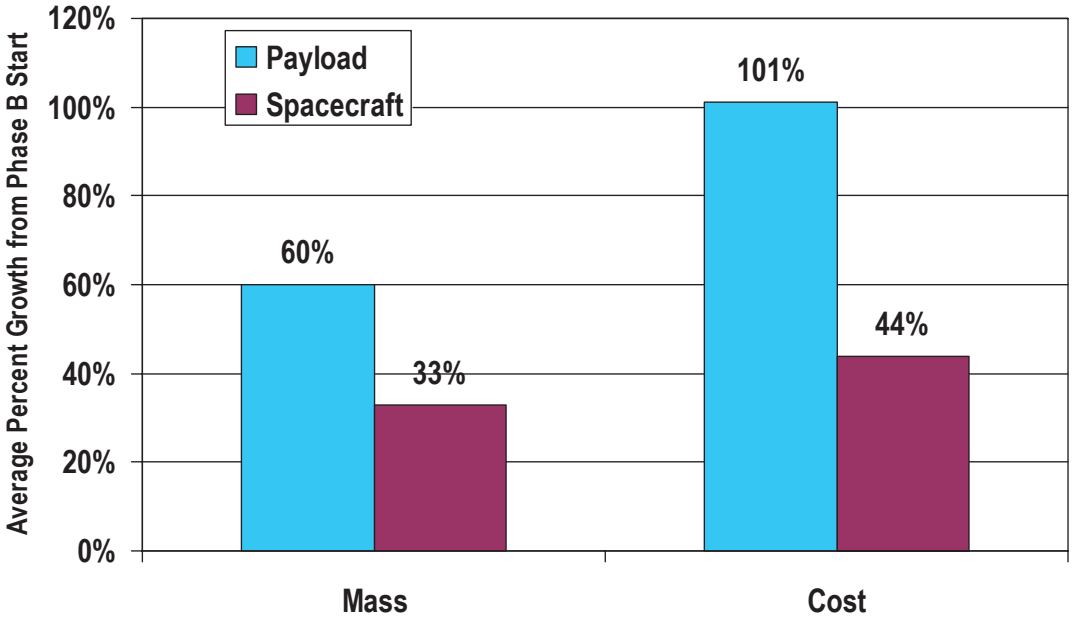

Figure 4: Relative Cost and Schedule Growth from Phase B Start of Instrument Payloads vs. Spacecraft

3. SUMMARY

The need for an instrument first, spacecraft second (IFSS) mission development approach was addressed. Based on historical data, over two-thirds of NASA missions experience some difficulty in developing science instruments. These instrument development difficulties are due in part to the immaturity of the instruments at the start of Phase B as can be seen in historical missions were the mass and cost growth of instrument developments is twice the growth experienced by the spacecraft. The corresponding instrument delivery delays result in mission cost growth at a ratio of two or three to one due to the "marching army" cost experienced by the other mission elements awaiting instrument delivery. By adopting an IFSS development approach, the marching army cost penalty can be addressed by allowing more time for the instrument to develop prior to initiating full mission development thereby decreasing total mission cost growth.

4. REFERENCES

[1] Bitten R., Emmons D., Freaner C., "Using Historical NASA Cost and Schedule Growth to Set Future Program and Project Reserve Guidelines", IEEE Aerospace Conference, Big Sky, Montana, March 3-10, 2007

[2] Freaner C., Bitten R., and Emmons D., "Inherent Optimism In Early Conceptual Designs and Its Effect On Cost and Schedule Growth: An Update", 2010 Program Management Challenge, Houston, Texas, 9-10 February 2010