SSC14-VII-10

Adaptation of Manufacturing to Mass Production of Nanosatellites.

Leonard Vance
Raytheon Missile Systems
3360 E. Hemisphere Loop
Building m10 M/S 9
Tucson AZ 85706
Ph. 520.746.2300
ldvance@raytheon.com

Rigel Woida
Raytheon Missile Systems
1151 E. Hermans Road
TU/801/D26
Tucson Arizona 85756
520.794.2785
Rigel.Woida-Obrien@raytheon.com

Chad Spalt
Raytheon Missile Systems
1151 E. Hermans Road
TU/801/D2
Tucson Arizona 85756
520.794.2963
Chad.Spalt@raytheon.com

ABSTRACT

Production of satellites in the United States has largely converged on a business model which focuses on large, highly capable units, engineered for exquisite performance, high mission assurance and long lifespans. As the capability of nanosatellite components matures, opportunities emerge to exploit these new technologies to develop disaggregated tactical support systems for the warfighter which would be low cost, survivable and responsive to individual needs. Raytheon, in concert with other vendors and the Defense Advanced Research Projects Agency (DARPA), has brought into existence automated production facilities designed for this purpose, which maintain the capability to produce nanosatellites such as SeeMe and Phoenix satlets concurrently.

The development of this manufacturing capability permits short term production runs of satellites as needed with a fraction of the cost of a dedicated production line. Detailed work flows derived from robotic work instructions provide a sound basis for assembly simulations, establishing confidence in unit price and schedule. A detailed account of this automated assembly line, along with current expansion plans is discussed, providing insight into future production capabilities.

BACKGROUND

Raytheon Missile Systems (RMS) is the free world's largest designer and manufacturer of tactical missiles, headquartered in Tucson Arizona, with over 14,000 employees and 2013 sales of 6.6 billion dollars. Since establishment in the 1950's, RMS had built over one million tactical missiles and maintains contracts with all US armed services as well as those from 40 other foreign countries.

In recent years, the tactical missile business has evolved towards smaller and lower cost rounds as customer emphasis has tilted increasingly towards manufacturing and affordability. Accordingly, RMS has invested significantly in automated assembly and test capabilities.

These resulting new assembly lines, designed for multiple missile products provide the company with the ability to eliminate single use production lines, significantly reducing the total capital necessary for missile manufacturing.

OVERVIEW

As the nano/microsatellite market starts to mature, opportunities emerge to apply these multi-use production lines to small spacecraft. Much of the same testing required for missiles is duplicated on these lines, permitting the addition of completely new and separate product, ie spacecraft, at relatively low cost.

Figure 1: Raytheon Missile systems Overview

Early versions of multi-use production lines have demonstrated hundreds of units produced per month distributed amongst entirely disparate programs. The addition of low cost, short term spacecraft into this process seems an opportunity to provide the US government with an inexpensive alternative method of accomplishing space missions.

MARKET ASSESSMENT

Multiple market assessments for small satellites have been completed over the past several years showing the expected increase in satellite production over the next

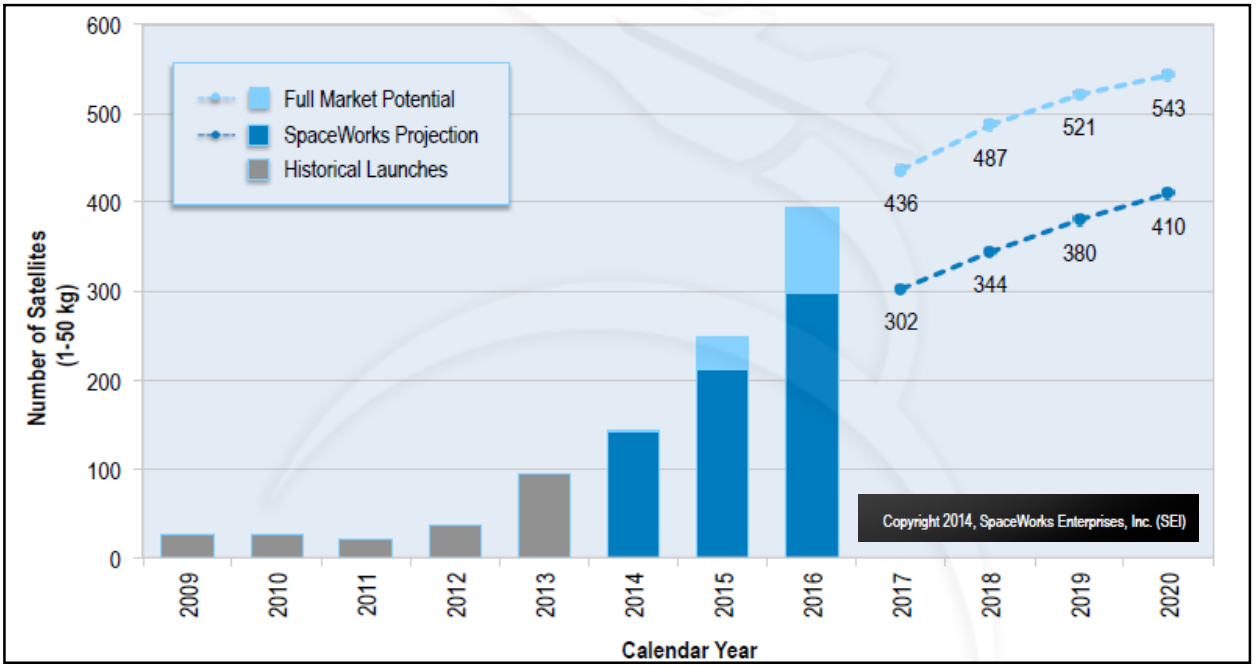


Figure 2: Overall Micro/NanoSat Market Assessment

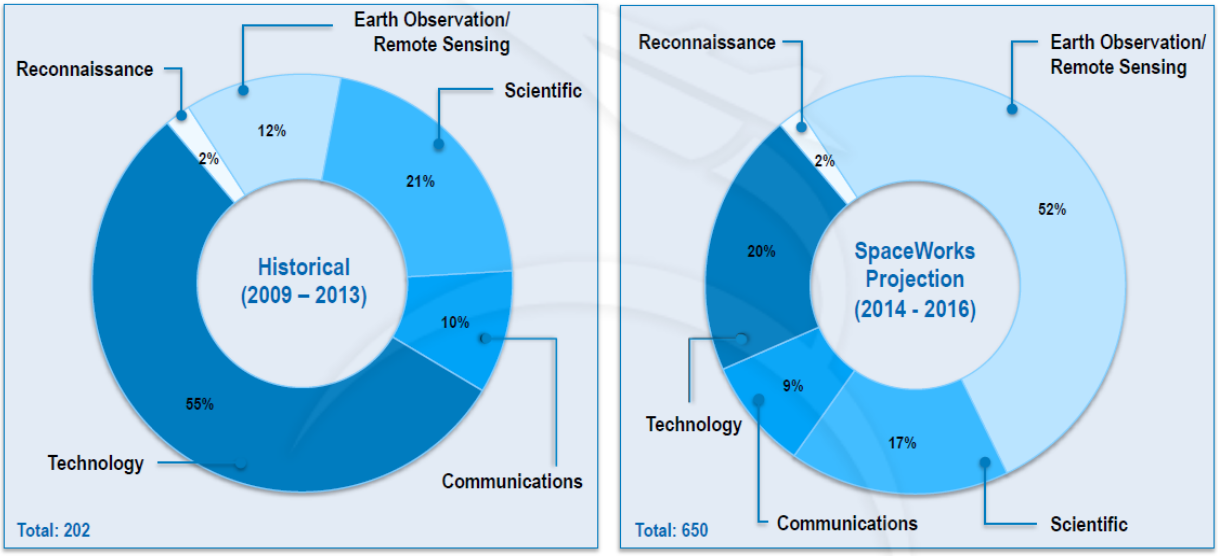


Figure 3: Mission Purposing: Historical vs Projected

seven years. Space Works' overall assessment, shown in figure 2 provides a top level view of the market and its projected growth. This indicates a market which is rapidly growing, with assessments supported by a significant increase in spacecraft produced in 2013.

A more detailed look at the evolution of missions follows in figure 3 showing that the emphasis on these missions is transitioning from technology development to actual applications such as earth observation and scientific measurement. These two charts, considered in combination suggest the possibility that the time is near to enter this fast emerging market

MULTI-USE MANUFACTURING

A significant amount of company IRAD has been expended during the last ten years towards updating missile manufacturing lines in anticipation of increased customer emphasis on quality and cost. Several multiple use production lines are already in use at Raytheon. These are typified by the automated electronics factory line shown in figure 4, testing a wide variety of missile electronics ranging from Air-to-Air to those for ballistic missile defense.

Figure 4: Automated Electronics Factory

Figure 5: Automated Assembly Factory

Another example is the Multi-Use Overall Assembly Line shown in figure 5, demonstrating progressive integration of two different missile systems on a single line. Here, motorized pallets move about the factory, shuttling parts from station to station and raising the tables to workstation height when human interaction is needed.

NANOSATELLITE MANUFACTURING ADPTATIONS

The next phase of production line development involves the use of multiple robots to speed assembly and improve overall quality. The Fusion test factory, has been designed as an assembly line for multiple missiles and/or satellites, utilizing industrial robots,

both fixed and on tracks, providing comprehensive automated test capability both for tactical missiles and small satellites.

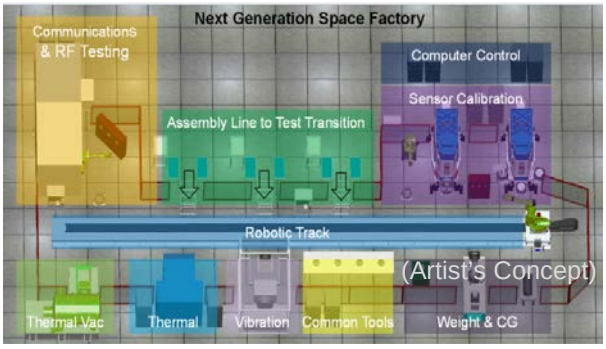


Figure 6: Next Generation Space Factory

Figure 6 illustrates the layout of the proposed system, incorporating semi-active laser test stations, as well as collimated light sources, an RF communications testing hood, thermal, vibe in addition to weight and CG. A remotely operable thermal vacuum chamber is currently being added to complete the suite for satellites. Figure 7 shows the current state of the system.

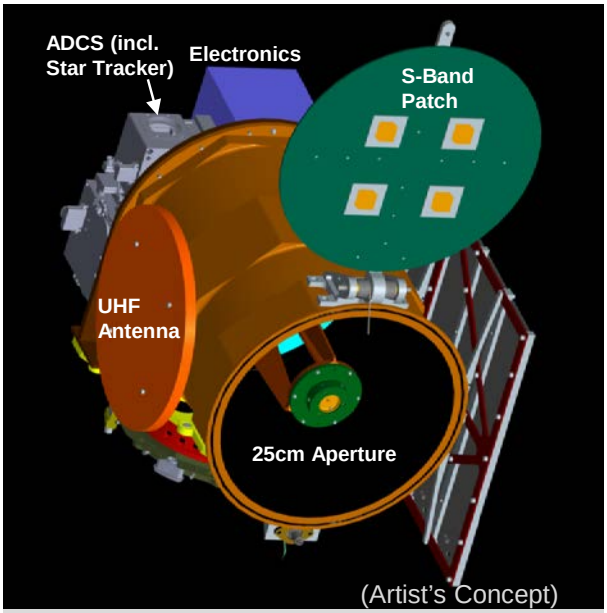
Figure 7: Current Space Factory Implementation

PLANS FOR ADAPTATION

Verification of the capability of this assembly line system is being performed on the Raytheon SeeMe program. SeeMe is a 20kg nanosatellite, based on the DARPA program by the same name for the purpose of providing NIIRS 5 quality imagery directly to the warfighter with a price tag of less than $500K per satellite.

Currently scheduled for launch in September 2015, the SeeMe satellite is specifically designed for mass production at an inexpensive price point.

RMS plans to exercise the techniques for assembling and testing SeeMe. An overview of the proposed spacecraft is given in figure 8. Assembly will be done this summer for a prototype and then again in the fall of 2014 for our flight unit as scheduled in September 2015.



SeeMe Goals

20 Kg Mass
September 2015 Launch
Full Function ADCS
UHF Command & Control
S-Band Image Downlink
NIIRS 5 capability
> 90 day lifetime
< 500K$ price at volume

Affordable, responsive NIIRS 5 imagery directly to the warfighter upon demand

Figure 8: SeeMe Overview