Adaptation of Manufacturing to Mass Production of Nanosatellites

Leonard Vance / Rigel Woida
Raytheon Missile Systems

Distribution Statement “A”
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Raytheon Missiles Systems – Operations

- World’s Largest Volume Tactical Missile Producer
  - $6.6 Billion in Sales
  - 33,500 Units Delivered In 2013
  - 14,000 Employees

- Manufacturing Operations
  - Air, Sea, Land, and Space Based Products
  - 6 Technology-Based Centers
    - 16 Factories located across 6 states
  - 24 Production Programs / 5 Process Factories
  - Integration, Test, Final Assembly
  - 1.75M ft² of Manufacturing Space

- World Class OSHA Safety

- Support Organizations
  - Manufacturing and Test Engineering
  - Facilities Services
  - Environmental Health & Safety
RMS Systems Manufacturing
Affordable, Adaptable, Secure and Sustainable

- Factory modernization
  - Reduce manufacturing variability and material handling
  - Use use of multi-product work centers
  - Increased use of technology

- Integration, colocation and collaboration of development and manufacturing teams

- Commonality and process focus in factory environments

- Employee engagement to quickly resolve issues

- Focus on affordability

Delivering Mission Assurance and Superior Results
RMS Factories of the Future Roadmap

Objectives

- Reduced labor cost
- Reduced cycle time
- Improved Quality
- Enhanced factory utilization
- Improved personnel and product safety
- Reduced variation and rework
- Accelerated manufacturing transition
- Increased productivity
- Process controls

Strategies

- Factory Automation
  - Assembly and test
  - Material Handling
- Infrastructure Automation
  - System to machine interface
  - Data management
- Variability Reduction
  - Statistical process control
  - Error proofing
- Lean Practices
  - Visual systems
  - Synchronized flow
- Engineering Integration
  - Design for FoF / platform
  - Family of missiles
- Test Strategy
  - Common architecture
  - Common platforms
- Employee Engagement
  - Designers collocated with FoFs
  - Employee ownership

FoF Journey

- Electro-Optics
- RF / Electronics
- PRESIDIO
- Integration
- Space

Implementation

- Automated Test Systems
- Automated and Robotic Assembly
- Robotic Conveyance

Transparent Information

The Future is NOW!

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5 Modern Capability Factories

- Over the past 5 years Raytheon has targeted modernization and automation of a series of their core competency’s areas. The result of which has been large reductions in labor, support, cycle time, test and floor space. These state of the art factories provide the perfect incubator for small space manufacturing.

Automated EO Sensor Factory (Tucson)

Automated ELX Factory (Tucson)

Automated All Up Integration Factory (Tucson)

Automated All Up Integration Factory (Huntsville)

Automated Product Assembly Cells (Tucson)

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Focus Areas for Small Space “Assembly”

- Raytheon assembly solutions focus on touch labor reduction, increase digital inspection & recording, increased process controls and mission assurance.

Automated Product Assembly Cell

COTS Pick and Place Robots

Digital Point of Departure Visualization & Sequencing

Custom Product Tooling

Rapid Adhesive and Cure

Real Time Sensor Feedback

Dispense System – Provides precise application of liquids!

Component Tooling – Allows unattended assembly!

End Effector Exchange – Provides flexibility of robot function!

Vacuum Pickup – Eliminates manual handling & cleaning of optics!

Rapid UV Cure – Reduces process time from 35 hours to 5 minutes!

dSAL Optics – Designed to support automated assembly!
Focus Areas for Small Space “Innovation”

- A key factor in Raytheon's ability to enable small space production is the Fusion Innovation Lab (FIL):
  - The FIL serves as the open collaboration lab that’s used to create Point of Departure designs.
  - FIL has engineering versions of the robotic systems used in the various factories to enable rapid prototyping, proof of concepts and integration.
  - Is a focus point for new products, technologies, TE and process improvement for the factory.
  - A synergistic team of supply chain, engineering, meteorology, factory support and the product leadership are located around this central location.
What tests are run in FIL 2014

- **Small Space Tests**
  - Star Tracker
  - MTF/Focus
  - IMU/Magnetometer
  - Reaction Wheel
  - Torquer Rods
  - Inertial Measurement Unit
  - Solar Power
  - GPS

Prototype Agnostic Test Capability

Pick and Place with SeeMe
Focus Areas for Small Space “Test”

- The Fusion test line mission is to provide the maximum flexibility to programs. It provides a Raytheon funded test suite of test stimuli, tied together with robotic automation:
  - Autonomous Material Handling & Single Operator Command & Control
  - Disturbed Test Systems (Visible Cal, IR Cal, IMU, RF, Vib, Thermal, TVAC, Weight, Balance)
  - Common Data Collection and Handling Tools
  - Backwards compatibility and integration of legacy TE onto the line
RMS Automated Final Acceptance Test Line for Satellites is Approaching Operational Status

- Traditional Space Manufacturing involves Multi-Billion dollar satellites delivered on multi-year centers
- Emerging nano-satellite companies may have unproven manufacturing capability
- Nanosatellite manufacturing is largely similar to tactical missile manufacturing
- Raytheon is pursuing multi-use assembly lines for a variety of complex and small mass platforms
- Nanosatellites can be built using RMS new high volume, low cost manufacturing investments

RMS offers mass manufacturing to the fast growing nano/micro satellite market
DARPA SeeMe Satellite Introduces Nanosatellite Production into Multi-Use Assembly Lines

Provide Proof of Concept for Satellite based Tactical ISR as a market enabler for nanosatellite responsive space

Include the following attributes:

1) Production Price less than $500K (by 24th unit)
2) NIIRS 4 in demonstration, traceable to NIIRS 5 in chosen (350km) orbit
3) Lifetime > 90 days
4) Direct image downlink to tactical user
5) Mass production capability

SeeMe demonstrates the plausibility of building nano/microsatellites on RMS multi-use production lines

September 2015 Scheduled Launch
NovaWurks HiSat in Fusion Test

- Integrated Prototype HiSat and robotics end effector
- Raytheon is under contract to build HiSats (to print) for scheduled Sept 2015 flight experiment
Summary

- Our production lines are modernized to provide multi-use capability
- Small Space manufacturing requirements are largely similar to RMS core business
- RMS is contractually proving this out with DARPA SeeMe and Phoenix programs
  - Scheduled Launch date September 2015

Small Sat mass manufacturing:
Now available - Without buying the line