Agenda

• NASA’s interplanetary Supply Chain (iSCM) for Exploration
  • Emphasis on Kennedy Space Center ground processing operations
  • Economic modeling to assess ISM 3D printing adaption and supply chain risk
  • Network modeling for sequencing interplanetary supply chain and logistics nodal positioning
  • In Space Manufacturing (ISM) Initiative
  • iSCM Value Proposition

• Summary
Space Shuttle Program (SSP) Orbiter Processing Concept Design Circa.1972
Actual Orbiter Processing Operations
Ineffective Communication
Key data “locked” in engineering
Increased Timeliness
Lack of Shared Knowledge
Increased Margin on Initial Quotes
Lack of IP Protection
Lack of classification for export
Supplier involvement

Assembly Quoting Challenges
Manufacturing Readiness
Industrial Base Viability
Spend and Demand Aggregation
Inadequate view of total cost
Difficult global part transition
Counterfeit Parts
Product Quality

Incomplete Specification Data
Increased indirect non-recurring cost
Increase in change order activity
Large inventory costs
Frequent Obsolescence occurrences
Lack of export controls
Poor supply chain readiness
SSP Ground Operations Cost Breakdown

10% Direct Processing Core Activities using SSP as Example

Design and Systems Engineering

L&L Ground Operations 11%
Operations Driver 5%
Indirect Operations 17%
Flight Element Logistics 16%
Ground Ops 26%
Infrastructure 19%
GSE Logistics 3%

90% of Cost are Indirect Processing Core Activities
(Based on SSP 2008 Budget)


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• 30% of suppliers NASA dependent
• 46% had no interest to support Commercial Human Space Flight
• 14% had no interest to support future NASA programs
• 19% of suppliers high risk of insolvency
• Manufacturing capacity utilization <50%
• NASA product Market Cap decreased
• 53% of suppliers support DoD
• 12 other Agencies impacted


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Supply Chain Post-Shuttle Lessons Learned

“For want of a nail a kingdom was lost” c. 1230 Freidank Bescheidenheit

- The space industry’s profit margins lagged behind A&D, and other high technology manufacturing sectors
  - Profitability was typically lower the further down the supply chain a company was situated from the first tier
  - Because of low visibility into suppliers below the Tier 1 level, it is difficult to assess resiliency and product quality of specific tiers or subsectors within the NASA Supply Chain
NASA Supply Chain Economic Resiliency Model

Product Demand Forecasting of Macroeconomic Influences
- It’s about Liquidity!

- Current Ratio
- Debt Ratio
- Net Profit Margin
- Altman Z Score
- Customer Diversity

- Dependency on Specific Customer
- Purchase Order Time Gap
- System Utilization
- Criticality/Sole Source
- Inventory Turnover

- Vertical Chain Visibility “Tier Mapping”
- Supplier Commonality/Interoperability
- Manufacturing Readiness Levels
- Technology Readiness Level
- SCOR® Key Performance Indicators
- Quality Considerations
- On-Time Delivery
- Number of Competitors
- Manufacturing Capacity
- Functional Capability

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Step 1. Data Sourcing – Content is King!

- **Data Sources**
  - D&B Hoovers
  - SBA
  - SAM (CCR)
  - US-Spending
  - VETBIZ
  - USGS
  - USFS
  - NOAA
  - GIDEPT
  - GOV-REP
  - US Census
  - Geospatial

- **Data Richness**
  - 450+ data points on 85 million+ companies
  - 2 billion+ government contract records over 5 years
  - Over 450,000 US government registered companies
  - Distinct company classifications
  - Company financial data
  - Number of employees by location
  - Geospatial risk
  - Geopolitical location
  - Government representation

- **Data Correlation**
  - DUNS
  - Company Name
  - Location
  - CAGE
  - Relationship
  - Geocode
  - Political
  - Risk
  - User Defined
  - And much more...
Supply Chain Economic Resiliency Model

Insert screen shots here
Visibility of the Complex and “Multi-functional” Supply Chain was achieved
MARS

Mars Half the size of Earth

687 One year on Mars
Number of Earth days it takes for Mars to make one revolution around the Sun

365 One year on Earth
Number of days it takes for Earth to make one revolution around the Sun

24 Hours, 39 minutes, 35 seconds
Length of a Martian day, known as a "sol"

-55 Degrees Celsius
Is the average temperature. When the sun is shining in the summer, the temperature near the Martian equator can reach 20 degrees Celsius, but it drops to -100 degrees Celsius at night!

144 Kilometres
Highest wind speed recorded on Mars

26 Kilometres
Height of Olympus Mons, the highest known mountain in the solar system (over three times the height of Mount Everest)

Because Mars's orbit is different from Earth's, there is one launch window every 26 months. Distance from Mars to Earth depending on its orbit.

Using current technology, it would take over two years for a team of astronauts to travel to Mars and back.

Water has been found on Mars in the form of vapour, ice and snow.
Campaign-Level Network Flow Modeling

NASA/MIT developed Supply Chain Model “SpaceNet”

• Network modeling for sequencing multi-commodity network flows
• High-fidelity analysis of logistics nodal positioning and flight manifest
• Models the balance of constraints such as mass transformation e.g. propellant
• To consider In-Space Manufacturing (ISM) infrastructure & Feedstock

\[
J = \sum_{(i,j,e) \in A} c_{ije}^+ x_{ije}^+ \\
\sum_{j: (i,j,e) \in A} x_{ije}^- - \sum_{j: (j,i,e) \in A} x_{jle}^- \leq b_i \quad \forall i \in I \\
x_{ije}^- = B_{ije} x_{ije}^+ \quad \forall (i, j, e) \in A \\
C_{ije}^+ x_{ije}^+ \leq p_{ije}^+ \quad \forall (i, j, e) \in A \\
x_{ije}^+ \geq 0 \quad \forall (i, j, e) \in A
\]

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What is In-Space Manufacturing (ISM)?

ISM is on-demand manufacturing using In-situ Resource Utilization (ISRU)

- Regolith-Based 3D Printing or with binder additives such as a Polymer feedstock
- Required for affordable, sustainable space operations beyond Low-Earth Orbit
- Years away from complementing supply chain but success is being realized;

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## Value Proposition from iSCM and ISM

<table>
<thead>
<tr>
<th>Value Source</th>
<th>SSP FY2004 BASELINE Cost¹</th>
<th>Improvement % Range²</th>
<th>Cost Improvement Assumed</th>
<th>Cost Improvement Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in material handling Labor Cost due to Less Inventory</td>
<td>175 M (Hardware)</td>
<td>10%</td>
<td>17.5 M</td>
<td>Less parts need reduced material/part Inventory handling costs</td>
</tr>
<tr>
<td>Finished Goods Inventory Reduction</td>
<td>229.3 M</td>
<td>15-33%</td>
<td>55.0 M</td>
<td>Change in manufacturing model; In-space demand supply visibility</td>
</tr>
<tr>
<td>Reduced Cost of Obsolescence</td>
<td>74.2 M ^3</td>
<td>30-50%</td>
<td>29.6 M</td>
<td>On-demand in-space manufacturing reducing or eliminating Earth-based sources of supply.</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>$478.1 M</strong></td>
<td><strong>20 - 25%</strong></td>
<td><strong>$102.1 M</strong></td>
<td>Reduced Logistics Footprint</td>
</tr>
</tbody>
</table>

Note 1: Baseline has been set based on NASA SSP Flight Element Logistics inputs and Federal Procurement Database (FPDS). Details available in NASA LLEGO Model.
Note 2: Benefit ranges have been estimated based on SAP customer and industry benchmarks. Note 3: SSP 2004 Transition & Retirement SLEP POP SCM Risk Budget. Critical Vendor Viability, DMSMS, Aging Hardware.

**Estimated Annual cost savings**

$100M - $135M
Summary

The End Game of iSCM

- Integrate with reliable and quality data sources
- Develop common data ontology
- Provide secure cloud-base & mobile device application for real-time data streaming capable of supporting:
  - Micro-simulation tools that model complex interdependencies between economic and critical infrastructure sectors
- Require lower-tier suppliers provide data and integrate with platform

Methodology to obtain the Value Proposition

- Constantly run economic resilience simulations
- Analysis of product sources and product quality (liquidity:quality)
- Model risk: natural disasters, transportation, economic, sole sources
- Assess advanced manufacturing technology readiness e.g. 3D Printing
- Ensure rapid response and mitigation to supply chain disruption

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