Concept of Operations Visualization in Support of Ares I Production

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Introduction

Boeing Production of Ares I Upper Stage and Instrument Unit

Boeing selected in 2007 to manufacture Ares I Upper Stage (US) and Instrument Unit (IU) to NASA’s design

- Architecturally similar to Apollo/Saturn 3rd Stage
- Requires use of latest manufacturing and integration processes to meet NASA budget and schedule targets

NASA Marshall Space Flight Center (MSFC) and Boeing are working together to develop cost effective and lean US/IU production

- Production at MSFC’s Michoud Assembly Facility (MAF) outside of New Orleans, Louisiana
- One of the largest manufacturing plants in the world (174,000 m²)
## Comparison of MAF Manufactured Stages

### Saturn/Shuttle/Ares

<table>
<thead>
<tr>
<th>Stage Type</th>
<th>Height (ft)</th>
<th>Dry Mass (lb)</th>
<th>Total Mass (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturn V (S-IC)</td>
<td>138</td>
<td>298,104</td>
<td>5.04M</td>
</tr>
<tr>
<td>Saturn V (S-II)</td>
<td>82</td>
<td>86,086</td>
<td>1.16M</td>
</tr>
<tr>
<td>Saturn V (S-IVB)</td>
<td>58</td>
<td>25,750</td>
<td>.262M</td>
</tr>
<tr>
<td>Shuttle ET</td>
<td>153</td>
<td>65,980</td>
<td>1.65M</td>
</tr>
<tr>
<td>Ares I US</td>
<td>84</td>
<td>38,600</td>
<td>.156M</td>
</tr>
<tr>
<td>Ares V EDS</td>
<td>74</td>
<td>50,144</td>
<td>.517M</td>
</tr>
<tr>
<td>Ares V Core</td>
<td>215.6</td>
<td>296,952</td>
<td>3.165 M</td>
</tr>
<tr>
<td>Past</td>
<td>10 m</td>
<td>6.8 to 10 m</td>
<td></td>
</tr>
<tr>
<td>Today</td>
<td>8.4 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future</td>
<td>5.5 m</td>
<td>10 m</td>
<td></td>
</tr>
</tbody>
</table>

*Overall Vehicle Height, ft*
Need for CONOP Visualization/Simulation

Reduces Life Cycle Cost during early design

- **NASA challenge:** convert MAF into 3rd generation liquid oxygen/hydrogen rocket stage factory
  - Minimize disruption to ongoing Shuttle External Tank operations
  - Produce 2 to 6 Ares I Upper Stages/year for ISS missions
  - Produce up to 2 Ares V vehicles/year for lunar missions

- **Production experience:** 80% of life cycle cost established during first 20% of design process
  - NASA tasked Boeing with producibility analysis for Ares Upper Stage
  - Boeing aircraft (e.g. 737, F-18, Chinook) and spacecraft (Shuttle, ISS) production demonstrate value of virtual manufacturing and CONOP visualization during early design

- Production and operation visualizations can reduce tooling, factory capacity, safety, and build process risks while spreading program support across government, academia, media and public constituencies
Promotes timely, concurrent and collaborative producibility analysis (Boeing) supporting Upper Stage Design Cycles (NASA)

- Assembly Simulation (30% - 45% typical savings)
  - Validates operation sequences & tooling concepts
  - Enables optimization of assembly processes
  - Reduces downstream production planning

- Human Factors/Ergonomics (45% - 55% typical savings)
  - Identifies hazardous operations (hardware/ personnel)
  - Ensures accessibility during assembly/test/ operation/maintenance

- Factory Definition and Analysis (50% - 75% typical savings)
  - Validates floor space & factory operations
  - Validates operation sequences & large scale tooling concepts
  - Highlights capital investment requirements
  - Identifies assembly anomalies
Ares I IU Production CONOP/Simulation
Validated avionics assembly and handling

- Movie Here
NASA and Boeing reduced overall Upper Stage production flow time at MAF by over 100 man-days to 312.5 man-days.

Identified technician access issues during Launch-48 hours to remove the Ares I Thrust Vector Control (TVC) Actuator Locks during Preliminary Design Review.

DELMIA virtual manufacturing simulation validated a 25% reduction in Upper Stage assembly man-days.
Boeing and NASA developed flight ops visualization analog to production visualization

- Provides context for Ares element (Ares I and V) production at MAF over many years
- Illustrates range of Constellation element types, scale of time and complexity of interfaces required of Ares vehicle family
- Presents benefits of Constellation investment by visualizing architecture and describing the benefits to the implementers (industry), owners (public) and financiers (government)

ICON provides interactive access to Ares using real mission parameters

- 2-D data (such as trajectory, or ephemeris data, operations schemas, slides, spreadsheets, movies, documents, or web-based data)
- 3-D data (such as CAD models, contour maps, terrain maps, etc.)
- Specific different user views (selectable cameras)
- ICON Here
Benefits of ICON Visualization
*Ares ISS, Lunar and Mars flight operations*

- Ability for user to configure mission encourages ownership and identifies areas for improvement
- Mission options (e.g., Orion abort) or spacecraft detail (e.g., Interstage components) added as needed
  - Allows quick customization for unique audience and tailoring of messages
- Effective, low cost advocacy, outreach and education tool
  - Used to help science community visualize potential Ares interplanetary applications
Conclusions

CONOP visualizations will be critical to sustaining Ares/Constellation

- NASA and Boeing have used a variety of visualization tools to enhance design producibility and more effectively understand Ares operations
- DELMIA and ICON visualization provides timely insight into potential system problems and allow cost effective evaluation of alternate approaches
- The collaborative nature of DELMIA and ICON visualization and simulation tools can significantly reduce design cycle time and encourage a diversity of involvement across Ares/Constellation elements
- These tools identify changes earlier in the life cycle where the cost of change is less and promotes greater interaction and ownership by a larger pool of Constellation constituents (government, industry, academia, media and public)