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The Application of Lean Thinking Principles and Kaizen Practices for the Successful Development and Implementation of the Ares I-X Flight Test Rocket and Mission

On October 28, 2009 the Ares I-X flight test rocket launched from Kennedy Space Center and flew its suborbital trajectory as designed. The mission was successfully completed as data from the test, and associated development activities were analyzed, transferred to stakeholders, and well documented. A positive lesson learned from Ares I-X was that the application of lean thinking principles and kaizen practices was very effective in streamlining development activities. Ares I-X, like other historical rocket development projects, was hampered by technical, cost, and schedule challenges and if not addressed boldly could have resulted in cancellation of the test. The mission management team conducted nine major meetings, referred to as lean events, across its elements to assess plans, procedures, processes, requirements, controls, culture, organization, use of resources, and anything that could be changed to optimize schedule or reduce risk. The preeminent aspect of the lean events was the focus on value added activities and the removal or at least reduction in non-value added activities. Trained Lean Six Sigma facilitators assisted the Ares I-X developers in conducting the lean events. They indirectly helped formulate the mission's own unique methodology for assessing schedule. A core team was selected to lead the events and report to the mission manager. Each activity leveraged specialized participants to analyze the subject matter and its related processes and then recommended alternatives and solutions. Stakeholders were the event champions. They empowered and encouraged the team to succeed. The keys to success were thorough preparation, honest dialog, small groups, adherence to the Ares I-X ground rules, and accountability through disciplined reporting and tracking of actions. This lean event formula was game-changing as demonstrated by Ares I-X. It is highly recommended as a management tool to help develop other complex systems efficiently. The key benefits for Ares I-X were obtaining unambiguous schedule margin, defining enabling options for risk reduction, and most importantly a stronger more unified team.



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Purpose of Work

- ◆ Promote a unique Kaizen method that proved to be a game-changing management tool as applied to the very complex Ares I-X rocket integration activity and flight test.
- ◆ Document a systematic approach that was instrumental in the success of the Ares I-X mission.



Stacking of the Ares I-X rocket at the Kennedy Space Center Vehicle Assembly Building as depicted by the final element being placed atop the Ares I-X Flight Test Vehicle (FTV) integrated stack.



Outline

- ◆ **Background and Highlights**
- ◆ **Preparation and Reporting**
- ◆ **Approach for Lean Event Success**
- ◆ **Summary**

This background photo captures the Ares I-X rocket at Kennedy Space Center Launch Complex 39 Pad B.



Background and Highlights (1/6)

- ◆ The purpose of the Ares I-X mission was to collect data for anchoring analytical models, informing designers, and reducing risk.
- ◆ The Flight Test Vehicle (FTV), ground systems and operations were a combination of heritage hardware and new design.
- ◆ Lean Events provided a forum to bring together talented folks from different organizations to devise ways to optimize processing and integration.



The FTV was 327 feet tall and only 26 feet shorter than the Apollo V Saturn Rocket.



Background and Highlights (2/6)

- ◆ An Ares I-X Kaizen/Lean Event was a preferred and often used method to examine processes, organization, plans, requirements, relationships, and other factors to improve overall effectiveness and efficiency.
- ◆ Ares I-X developed a unique approach/formula based on proven Kaizen methods.
 - This approach was primarily used to obtain schedule margin, however this activity produced other benefits such as a stronger, better, and more unified and integrated team.
- ◆ Each event was generally conducted in a week.





Background and Highlights (3/6)

- ◆ **The FTV was composed of multiple elements:**
 - Crew Module/Launch Abort System Mass and Shape Simulator
 - Upper Stage Mass and Shape Simulator
 - First Stage
 - Roll Control System
 - Avionics

- ◆ **Kaizen gatherings were used to examine element processes with respect to the bigger integration challenge of finding mutually acceptable changes for reducing processing time.**





Background and Highlights (4/6)

◆ Major flight operations included:

1. Fly Away Maneuver performed to clear the launch tower with margin.
2. Staging/separation of First Stage from USS.
3. Controlled descent of the First Stage using tumble motors and parachutes.

◆ At lean events professionally trained Kaizen Black Belts guided small group discussions to consider ideal methods for doing business and affecting processes.

- The combination of ideal and reality when balanced produced sound alternatives.





Background and Highlights (5/6)



- ◆ An empowered Mission Management Office was effective in leading Ares I-X from a set of objectives through many major milestones and key decisions.
- ◆ Experts, both technical and programmatic, direct and independent, from across the country agreed to meet as-needed to ensure the system met requirements and was ready for flight.
- ◆ Each lean event was founded on thorough preparation and a dedicated technical team that provided key data for making major decisions.





Background and Highlights (6/6)



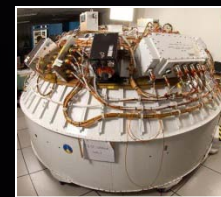
◆ Key schedule challenges included:

- Defining Environments and Loads
- Manufacturing Large Structures
- Integrating Heritage Hardware and New Hardware
- Integration of a Distributed Work Force
- Verification of Requirements via Test and Analysis
 - Also, the preparing paperwork.
- Transporting Elements



◆ Discipline was the key to successful events.

- Don't waiver from the approach/formula.
- Select a strong core team.
- Realize dead-ends.
- Enforce rules-of-engagement.
- Obtain management support.
- Follow-up.
- Event leader must enforce the game plan.
- Each participant enabled to negotiate for their organization/IPT.





Preparation and Reporting (1/3)



- ◆ **Lean events were based upon charters and a clearly stated business need.**
 - “Identify schedule opportunities and risks to support an overall Ares I-X flight day that is 60 days earlier than current baseline.”
- ◆ **Lean events documented current state, formulated an ideal state, and produced an effective future state.**
- ◆ **Enablers and derived actions were recorded to mitigate risks and highlight decisions needed.**
- ◆ **Reporting started on day one of each event and continued until the stakeholders were briefed.**



Launched Oct. 28, 2009

I. Business Need: Identify schedule opportunities and risks to support an overall Ares I-X flight day that is 60 days earlier than current baseline.	
II. Current Condition: <ul style="list-style-type: none">• Undefined items have slowed progress as noted by the following:<ul style="list-style-type: none">• Requirements definition and finalization• Architecture• Environments• Process is standardized, well understood and proven• Highly integrated• System level and DFI testing requirements are unscheduled or optimistic	III. Target Condition (Proposal): <ul style="list-style-type: none">• Established hard dates for requirements, architecture, environments, and early delivery authorizations• Aligned delivery dates with requested 60 day pull back• Moved harness deliveries from 8/15/08 to 4/15/08• Moved stack vehicle back to TBD date to be established at the Ground Operations lean event• Avionics schedule to be integrated with results from First Stage Lean Event



Preparation and Reporting (2/3)

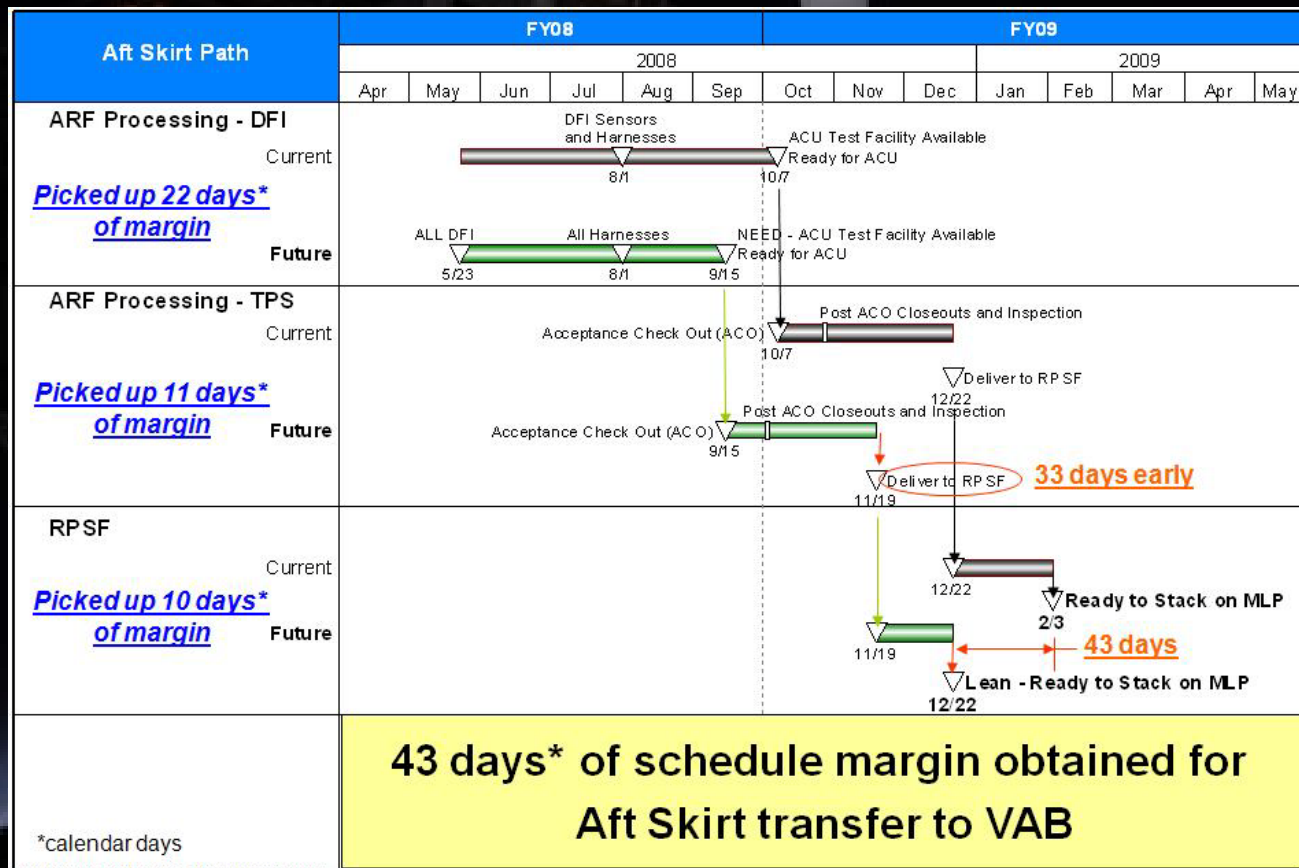
- ◆ The final report for each event was largely based on the schedule supported by a list of enablers
 - The purpose of the Enabler/Action List was to mitigate risks or document decisions needed to effectively initiate the new processes.

Item #	Risk Rating	Enabler (Action) Description	Benefit	Actionee	Due Date
1	G	Approve use of Atlas VSS as appropriate	Minimize/ eliminate un-necessary verification re-work	Flynn	8/7/07
2	G	Avionics IPT empowers LSE to approve verification activities (i.e., VSS method, traceability, and criteria)	Minimize/ eliminate additional reviews and table-tops	Flynn	8/7/07
3	G	Assign Verifiers prior to verification activity. Note: Verifiers cannot be testers - must be independent.	Eliminates formal audit	Carter	ACDR (11/11/07)



Preparation and Reporting (3/3)

- ◆ An updated schedule was delivered as the prime product.
 - For all Ares I-X Lean Events the product was the schedule.
 - The current state was compared to the future state and schedule margin was reported.





Approach Formula (1/2)

1. In advance of the meeting set clear objectives, prepare base materials, select participants, obtain commitments, and coordinate with the event champion. Have a clear vision.
2. Develop a charter.
3. The sponsor should make the lean event a priority.
4. The event champion should address the team.
5. Set effective rules-of-engagement (e.g., 100% commitment).
6. Utilize Lean Six Sigma coaches to guide small group discussions.
7. Hand-select participants for small group discussions.
8. Develop a core team to run each event.
9. Event leader must enforce the rules-of-engagement and implement the formula.





Approach/Formula (2/2)

10. Review the current state, construct an ideal state, and formulate a future/target state.
11. Develop an enabler plan including associated assumptions and actions.
12. Establish esprit de corps via a dinner, team photograph or other.
13. Create a parking lot for unsolved topics.
14. Standardize the report template to include an executive summary, assumptions, results, enabler plan, participants list, conclusion, and back-up data (e.g., processes).
15. Core team needs to include a head scheduler and a systems engineer to check and integrate the results, prepare the final report, and participate in event planning and post event tracking of actions.
Note: the entire core team for Ares I-X was composed of an event leader, head facilitator, scheduler, and systems engineer.
16. Report out to the sponsor on the last day of the event.
17. Track progress after the event.





Summary

- ◆ The Ares I-X Mission Management Office lead over 10 very successful lean events by a formulating and applying a strict format/approach/formula.
- ◆ By following the approach with dedication and leadership Ares I-X was able to control its schedule, unify its team, and build a rocket resulting in very successful mission.



Stakeholders at an Ares I-X press conference.



An Ares I-X team gathering after the successful flight test readiness review.



One of many awards received by the Ares I-X team