Composite Cryotank Technologies and Demonstration (CCTD) Project Overview

Composites Materials and Manufacturing Technologies for Space Applications Technical Interchange Meeting

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NASA Marshall Space Flight Center
May 6, 2015

Overall Project Objective

The fundamental goal of this project was to provide new and innovative cryotank technologies that enable human space exploration to destinations beyond low earth orbit such as the moon, near-earth asteroids, and Mars.

The goal … to mature technologies in preparation for potential system level flight demonstrations through significant ground-based testing and/or laboratory experimentation.

Composite Cryotank Project Goals

Objective: Advance technologies for lightweight cryotanks for heavy lift vehicles + spin-off capabilities for multiple stakeholders - NASA, DOD, and Industry

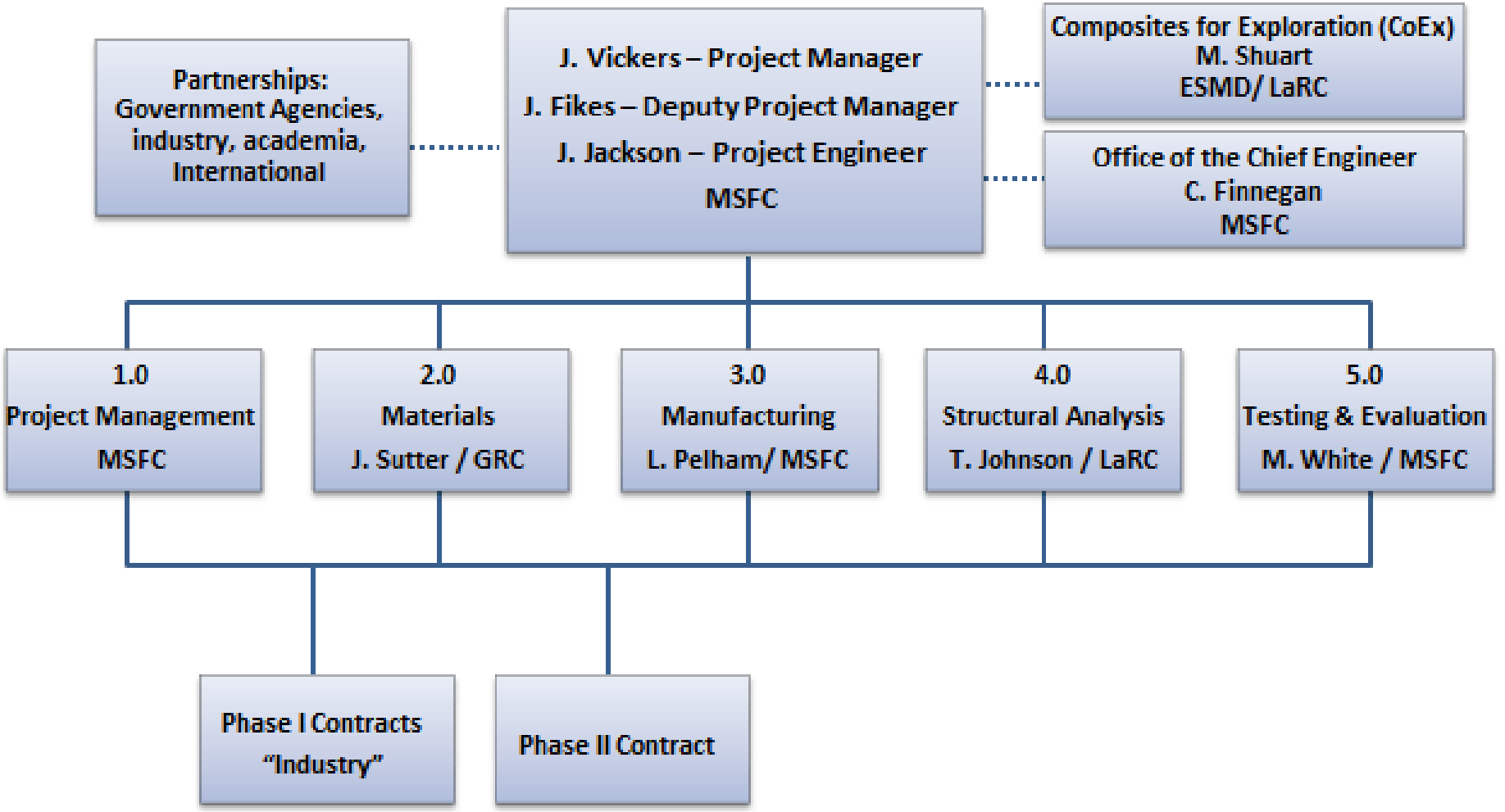
Concept: Develop and demonstrate composite tank critical technologies – **Materials, Structures, and Manufacturing - Out-of-Autoclave**

Approach: Focus on achieving affordability, technical performance, verified through agreement between experimental results and analysis predictions

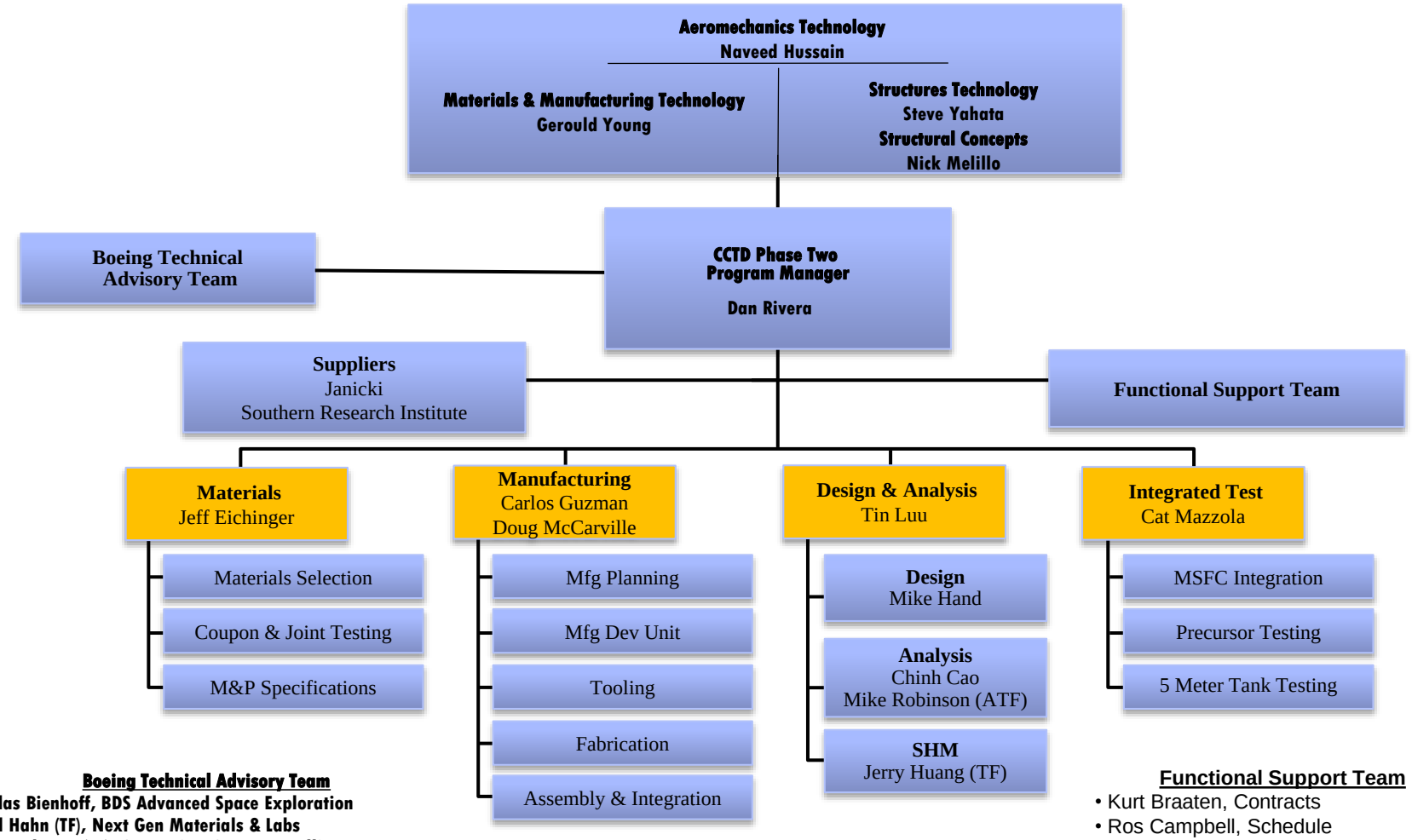
Goal: Produce a major advancement in technology readiness; successfully test a 5.5-meter diameter composite hydrogen fuel tank, achieve:

- **25-30% weight savings**
- **20-25% cost savings**

NASA Project Organization and Key Personnel



Boeing Organization



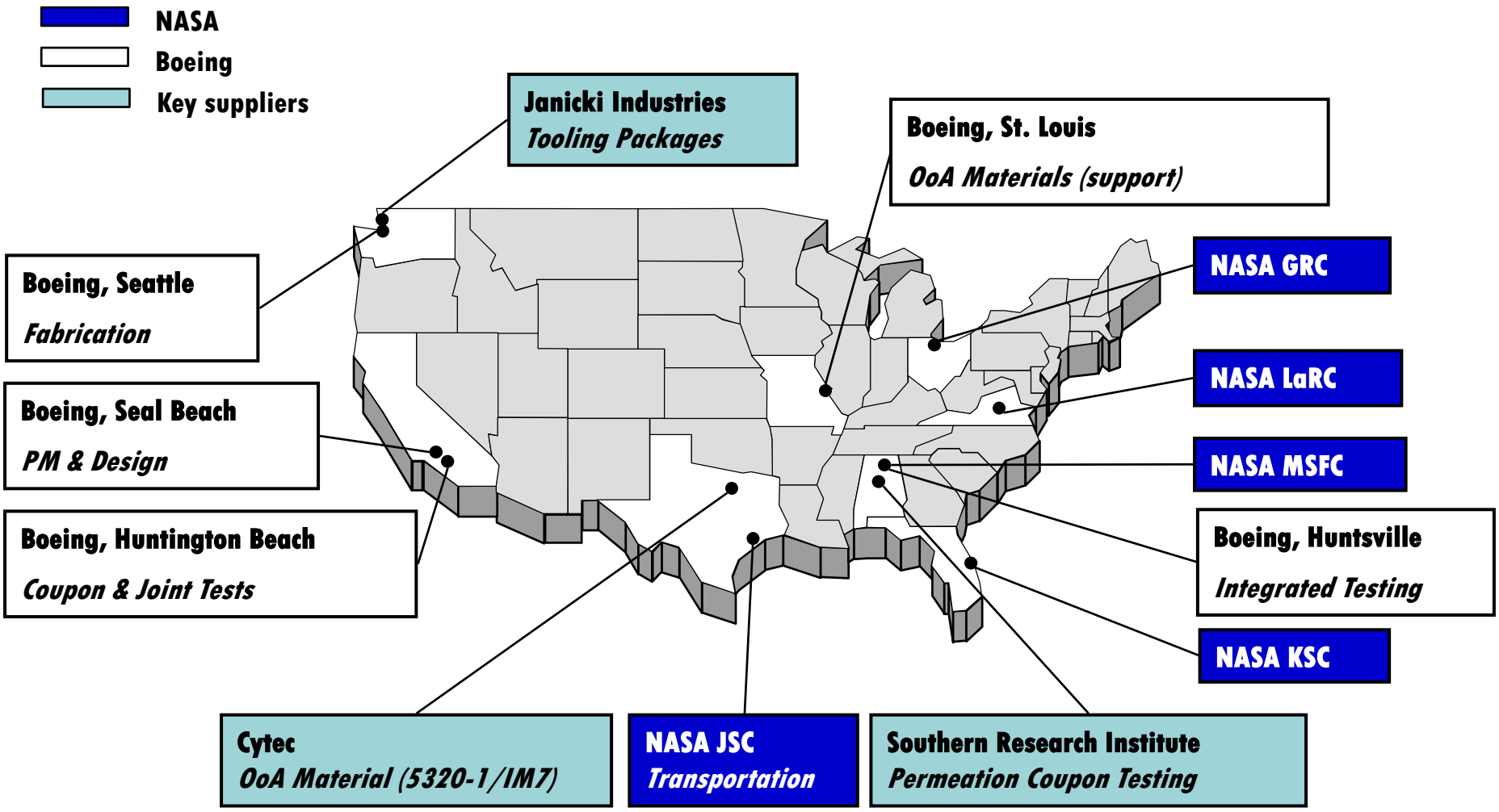
Boeing Technical Advisory Team

- Dallas Bienhoff, BDS Advanced Space Exploration
- Gail Hahn (TF), Next Gen Materials & Labs
- Brice Johnson (TF), Composites & Non-Metallics
- Don Barnes (ATF), BDS/Exploration Launch Sys
- Al Olsen, Propulsion Technology
- Marc Piehl (TF), Primary Structural Bonding
- Kurtis Willden (ATF), Composite Fabrication
- Richard Bossi (STF), Non-Destructive Evaluation

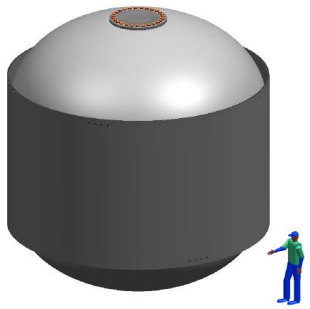
Functional Support Team

- Kurt Braaten, Contracts
- Ros Campbell, Schedule
- David Sanchez, Finance
- Mark Mihalco, Supplier Mgmt
- Denise Boss, Data Mgmt
- Roger Smith, Quality
- Charlie Conway, Safety
- Jeff Fukushima, ERB/MRB/CCB

NASA & Industry Team



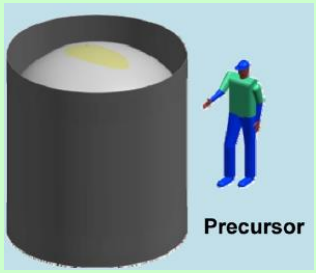
Building Block Program Culminated With 5.5m Cryotank

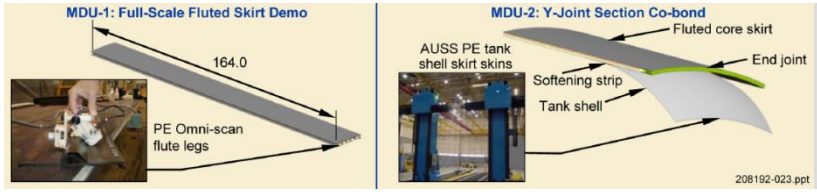


5.5 meter Tank

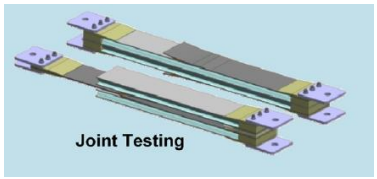
Available to support 5.5m Tank

2.4 meter Precursor Tank

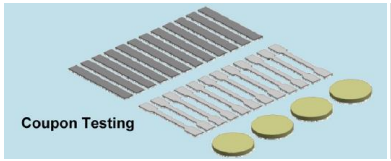




Manufacturing Demonstration Units



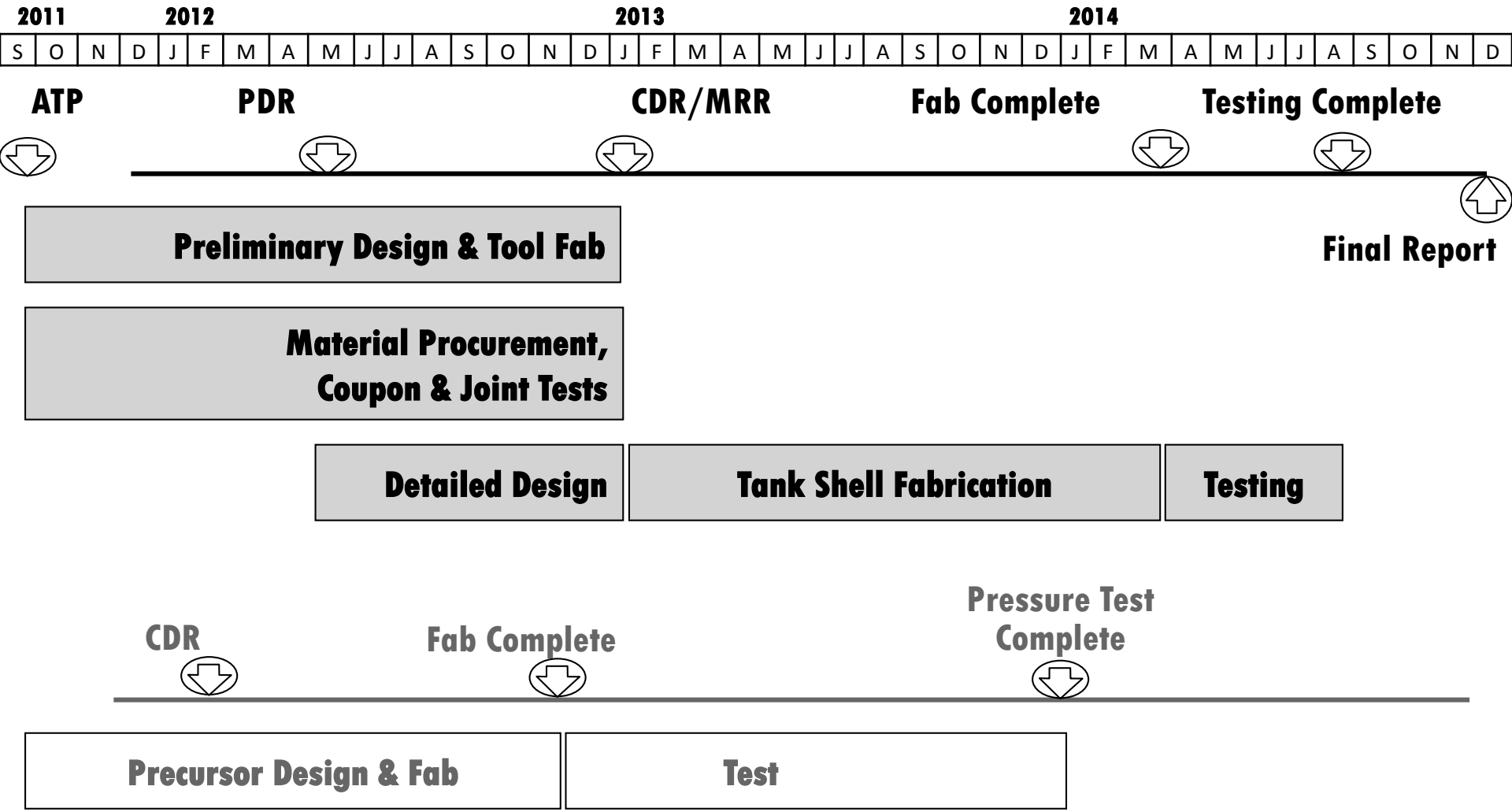
Joint Testing



Coupon Testing

Building block approach essential to successful technology maturation

Schedule Overview

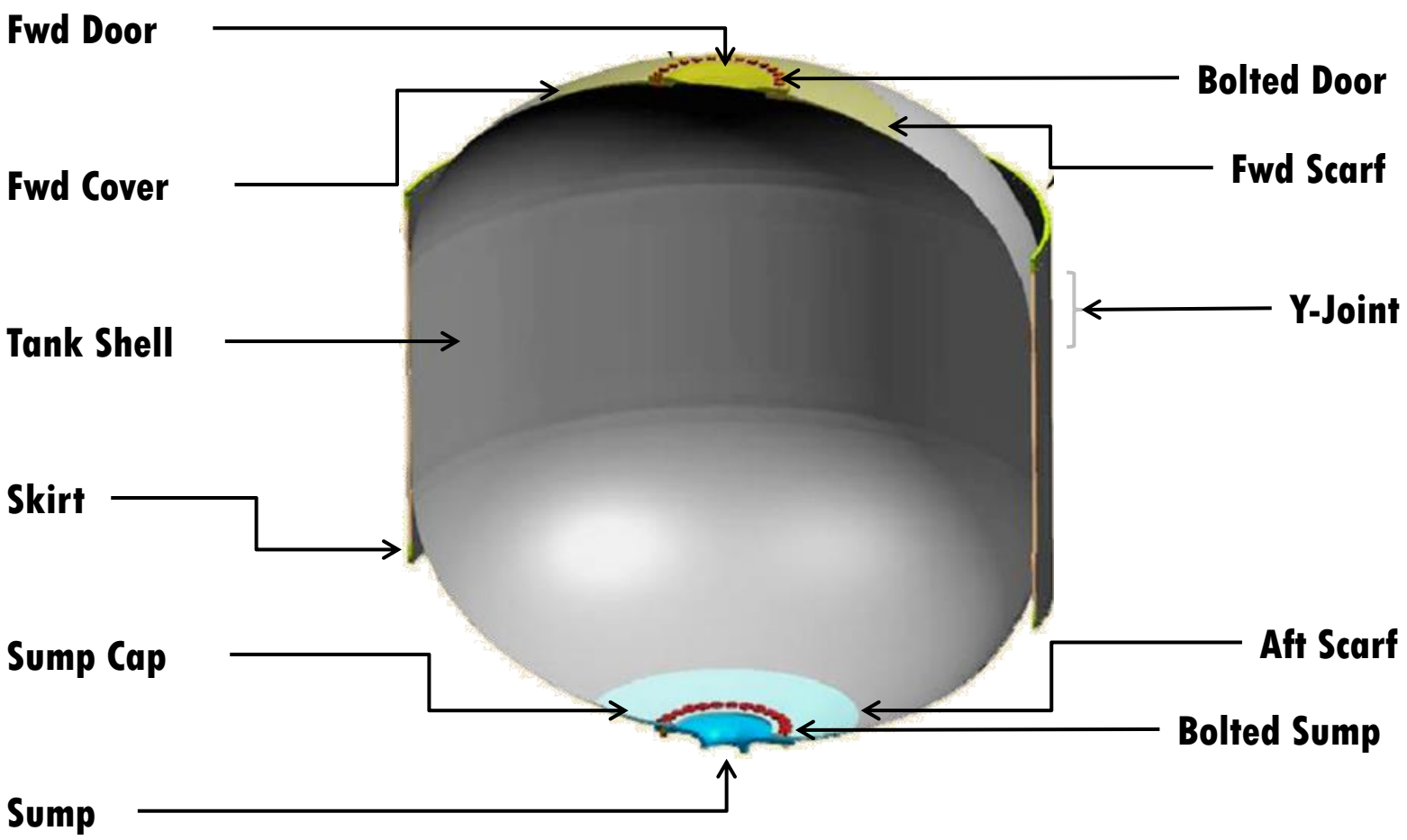


Saved 13 months in comparison to typical Serial Development

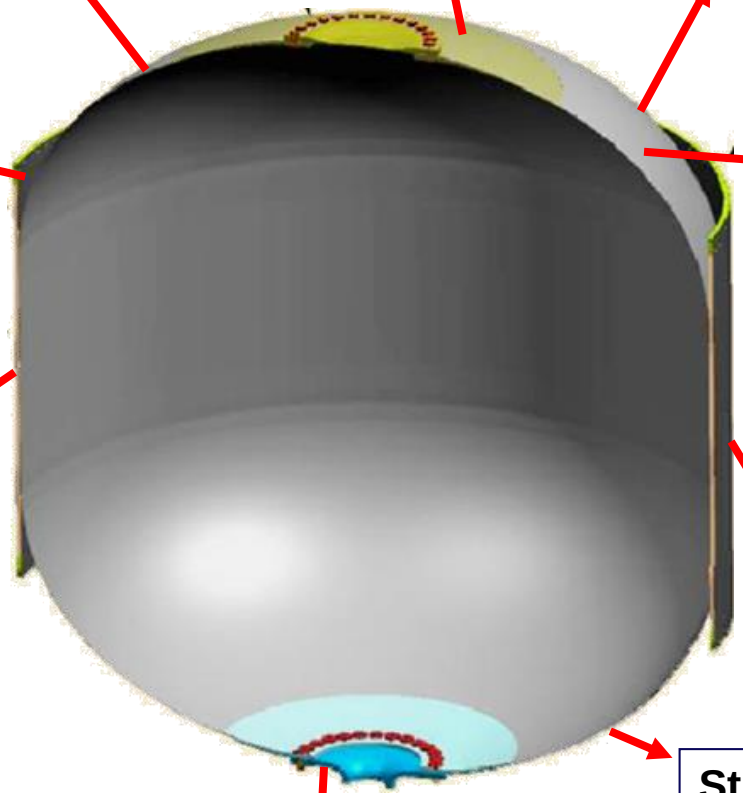
CCTD Key Terminology

Major Components

Major Joints



Technologies Matured by CCTD



Large Scale, OoA (5320-1/IM7) Design & Manufacturing

Structurally Efficient Bonded Scarf Joints

Automated Fiber Placement of Thin Tow

Shear Peak Reduction Structures

Permeation Resistant Hybrid Laminate

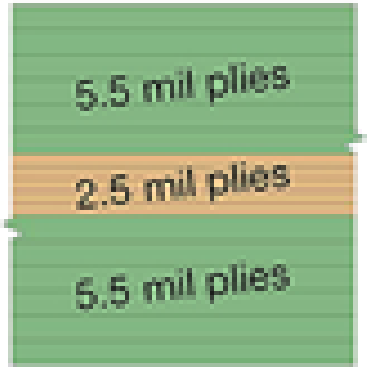
Ventable and Purgeable Sandwich Structures

Structural Health Monitoring Using Acoustic Emission Sensor Array

Composite Cryogenic Bonded Joints

Major Accomplishments

- **Large AFP test article using 5320-1/IM7**
- **70gsm fiber placed cryotank (hybrid laminate)**
- **Benefits:**
  - **Enables Out-of-Autoclave manufacturing**
  - **Meets material out time**
  - **Provides permeation barrier**

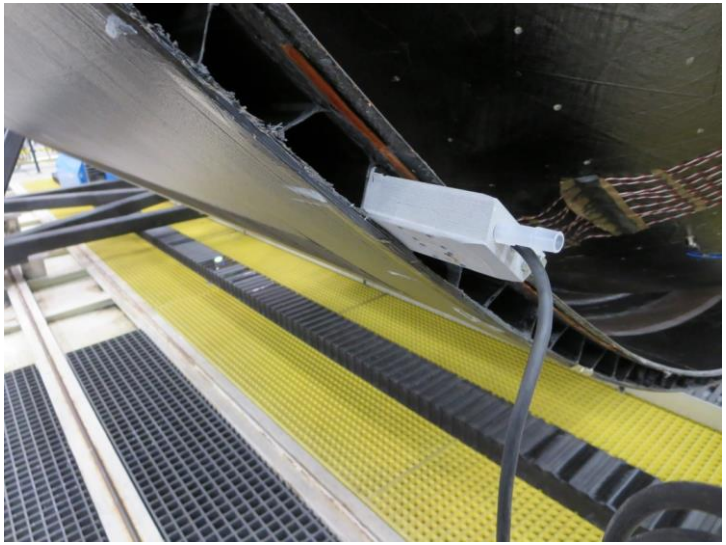


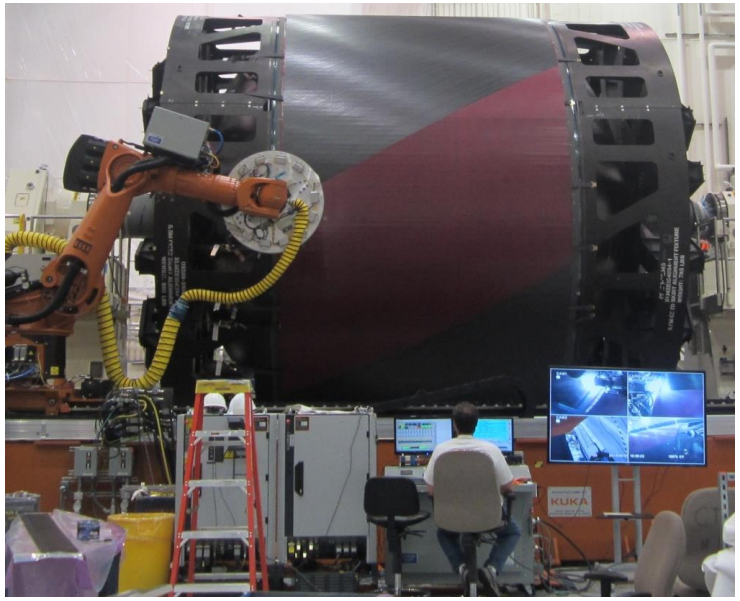
Major Accomplishments

- **Large scale, spherical segmented tool**
  - **Enables lightweight, 1-piece tank shell**
  - **Successfully used to fabricate cryotank**
  - **Successfully extracted**

Major Accomplishments

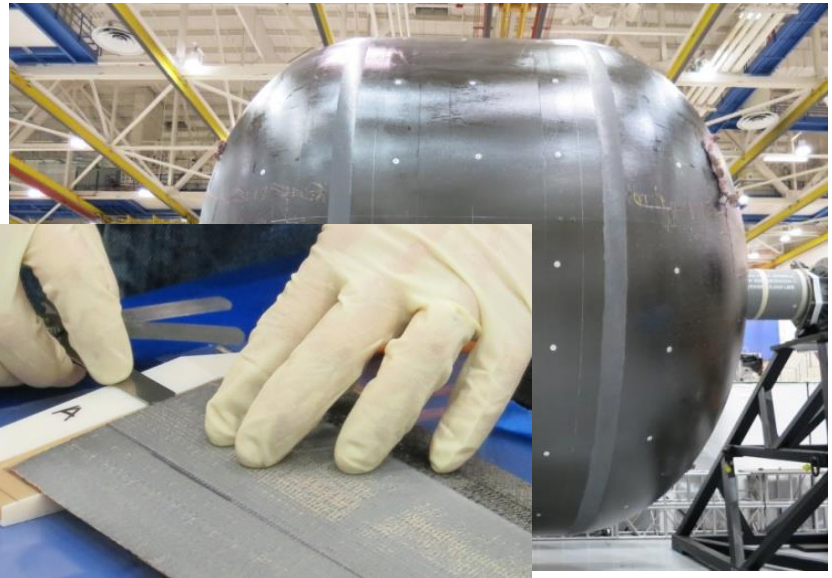
- **Large scale, Gr/Ep fluted core sandwich & NDI**





Major Accomplishments

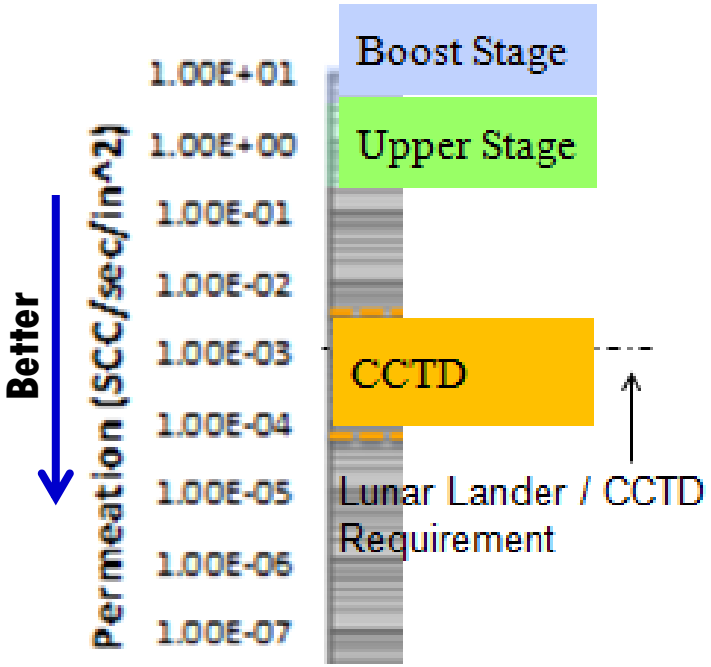
- **Cold temperature softening strip.**
- **All composite bolted cover joints.**



Major Accomplishments

Permeation Reduction:

- Hybrid laminate with thin plies prevented microcracking and reduced permeation levels.
- Design meets upper stage & booster stage calculated permeation allowable.
- To improve performance further:
  - Improve OoA AFP materials & processes
  - Increase number of thin plies
  - Autoclave cure



Major Accomplishments

Largest , Successfully Ground Tested Composite Cryotank

Ground Test Summary

- ✓ 83 pressure cycles
- ✓ 2 thermal cycles
- ✓ 2 max pressure cases
- ✓ 1 combined load cycle

Data Acquired

- Load/strain response
- Thermal response
- Laminate permeation rate
- Bolted joint performance

August 29, 2014
Marshal Spaceflight Center, Huntsville

Projected Composite Cryotank Benefits

	Reference	Composite	Weight Savings
10 meter (2011, Phase 1)	**NASA Al- LI 11,000lbs**	**6,700lbs**	**39%** (4,200lbs)
10 meter (2014, Phase 2)	**NASA Al-Li 11,000lbs**	**7319 lbs** **+ 619lbs for acreage & fwd joint**	**33%** (3,681lbs)
5 meter	Delta IV Al – 2219	CCTD Phase 2 Test Article	**33%**

CCTD Overview Summary

Prior Barriers
…. to Application of Large-Scale Composite LH2 Tanks

- **Manufacturability** – Scalable automated fiber placement & tooling.
- **Strain Limits** – Capable of 5,000με.
- **Y-Joint Strength** – Achieved 58psi at LH2 temp, despite low margins.
- **Bolted Joint Seals** – Demonstrated composite joint w/ furon omniseal.
- **Hydrogen Permeability**
  - Out-of-Autoclave – Thin plies significantly reduced permeation.
  - Autoclave – Hybrid laminate coupon did not permeate.