Completed Project (2012 - 2016)

Advanced Manufacturing Technologies (AMT): Advanced Near Net Shape Technology Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)

ANTICIPATED BENEFITS

To NASA funded missions:

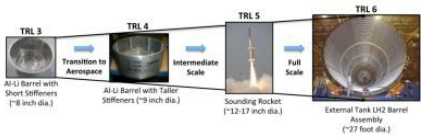
NASA missions funded through the STMD Game Changing Development Program, HEOMD Exploration Systems (SLS, MPCV) and Commercial Space Development programs, will benefit from the Integrally Stiffened Cylinder (ISC) process through manufacture of launch vehicle structure sub-elements at lower cost and with improved reliability and performance. The ISC process will greatly expand cryogenic tank barrel design space enabling greater structural performance benefits and significant mass savings.

To the commercial space industry:

Commercial launch providers will benefit from the reduced cost and improved reliability and performance of components manufactured using the Integrally Stiffened Cylinder (ISC) process. Domestic and international commercial launch vehicle developers and providers have expressed interest in partnering with NASA to develop the ISC process for applications on their suites of launch vehicles.

DETAILED DESCRIPTION

Develop and mature manufacturing technology to enable fabrication of single-piece integrally-stiffened launch vehicle structures to replace expensive, heavy, and risky multi-piece welded assemblies.



TRL maturation approach for the Integrally Stiffened Cylinder (ISC) process. Intermediate scale-up for Sounding Rocket demonstration. Long term goal to pursue large-scale cryogenic tank structures.

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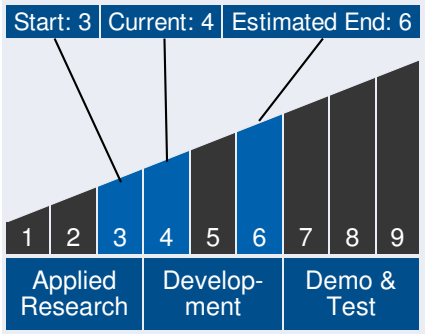
Technology Maturity



Management Team

Program Executive:

- Lanetra Tate

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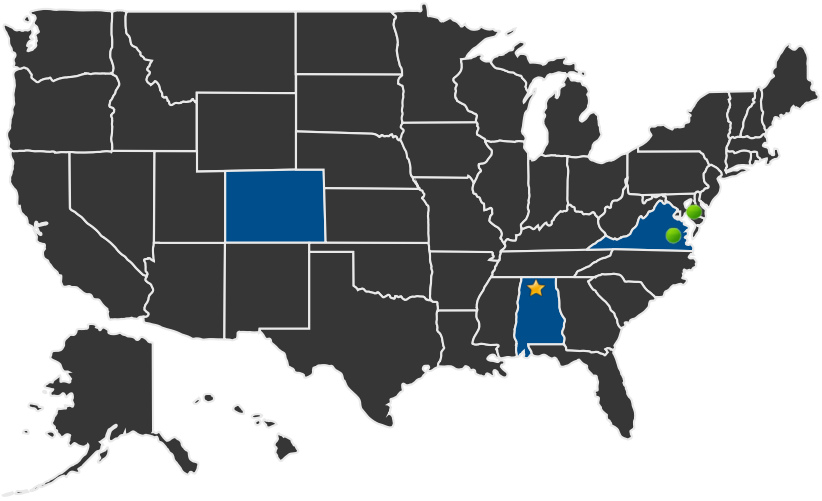
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Marshall Space Flight Center

Supporting Centers:

- Langley Research Center
- Wallops Flight Facility

Contributing Partners:

- Leifeld Metal Spinning
- Lockheed Martin Space Systems Company
- MT Aerospace

Management Team *(cont.)*

Program Manager:

- Mary Wusk

Project Manager:

- John Vickers

Principal Investigator:

- Lanetra Tate

Technology Areas

Primary Technology Area:
Launch Propulsion Systems (TA 1)
└ Liquid Rocket Propulsion Systems (TA 1.2)
└ RP/LOX Based (TA 1.2.2)
└ Large F-1 Class Gas Generator (GG) Cycle Engine (TA 1.2.2.2)

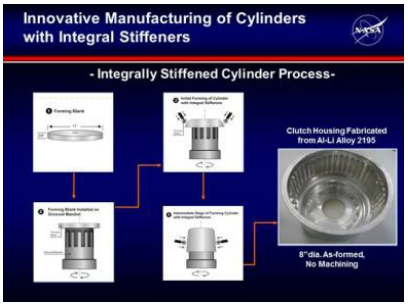
Additional Technology Areas:
Launch Propulsion Systems (TA 1)
└ Ancillary Propulsion Systems (TA 1.4)
└ Main Propulsion Systems (Excluding Engines) (TA 1.4.2)
└ Advanced, Low-Cost Cryogenic and Rocket Propellant (RP) Components (TA 1.4.2.1)

Materials, Structures, Mechanical Systems and Manufacturing (TA 12)
└ Manufacturing (TA 12.4)

Advanced Manufacturing Technologies (AMT): Advanced Near Net Shape Technology Project

IMAGE GALLERY

Scale-up and process modifications achieve taller stiffeners.



Schematic of the Integrally Stiffened Cylinder (ISC) process and image of the first successful fabrication of a clutch housing using Al-Li alloy 2195.

DETAILS FOR TECHNOLOGY 1

Technology Title

Advanced Manufacturing Technologies: Advanced Near Net Shape Technology

Technology Description

This technology is categorized as a hardware component or part for manned spaceflight

The objective of the Advanced Near Net Shape Technology (ANNST) project is to radically improve near net shape manufacturing methods from the current technology/manufacturing readiness levels (TRL/MRL 3-4) to the point where they are viable candidates (TRL/MRL 6) for shortening the time and cost for insertion of new aluminum alloys and revolutionary manufacturing methods into the development/improvement of space structures. Conventional cyrotank manufacturing processes require fabrication of multiple pieces welded together to form a complete tank. A variety of near net shape manufacturing process have demonstrated excellent potential for enabling single-piece construction of components such as domes, barrels, and ring frames. Utilization of such processes can dramatically reduce the extent of welding and joining needed to construct cryogenic tanks and other aerospace structures. The specific focus of this project is to successfully mature the Integrally Stiffened Cylinder (ISC) process in which a single-piece cylinder with integral stiffeners is formed in one spin/flow forming process.

Structural launch vehicle components, like cryogenic fuel tanks (*e.g.* Space Shuttle External Tank), are currently fabricated via multi-piece assembly of parts produced through subtractive

manufacturing techniques. Stiffened structural panels are heavily machined from thick plate, which results in excessive scrap rates. Multi-piece construction requires welds to assemble the structure, which increases the risk for defects and catastrophic failures. Weld regions require increased material thickness to offset reduced material properties in the weld metal and require costly NDE inspections. For example, the previous Space Shuttle External Tank (27.5 feet in diameter x 154 feet tall) had a material scrap rate of nearly 90%, resulting in ~ $8 million per tank in wasted material and had roughly half a mile of welds. Multi-piece machined and welded construction is 30+ year-old technology that works but is material inefficient, expensive, and risky. There is significant room for improvement with adoption of advanced manufacturing technology, which can be applied across multiple platforms.

This project seeks to develop and adapt manufacturing technology currently used in production of small steel automotive parts to enable fabrication of single-piece stiffened metallic launch vehicle structures using aerospace grade aluminum-lithium (Al-Li) alloys. The novel integrally stiffened cylinder (ISC) process will improve manufacturing efficiency and structural performance by producing single-piece stiffened barrels in one manufacturing process through combined spin- and flow-forming operations. Such a technique has never before been applied to launch vehicle structures. If successful, this will revolutionize the way integrally stiffened, metallic structures are fabricated with projected weight savings of up to 30%, cost savings of 40%, and the elimination of all longitudinal welds compared to the current state-of-the-art practice. Additional performance benefits will be realized through selective reinforcement with metal matrix composite materials incorporated into a hybrid launch vehicle structure.

The ANNST project has demonstrated transition of the ISC process from forming with automotive steel to an aerospace Aluminum-Lithium (Al-Li) alloy through successful fabrication of a typical automotive component. Further process optimization has shown successful increase in stiffener height from gear teeth to cryogenic tank barrel scale stiffeners.

Laboratory experiments have demonstrated the potential to selectively reinforce the stiffeners top using metal matrix composite materials. Initial testing of small-scale reinforced stiffeners showed a 30% increase in bending stiffness with only a 1% increase in mass.

Capabilities Provided

Successful development of the Integrally Stiffened Cylinder (ISC) process will enable the capability to produce stiffened cylindrical launch vehicle components in a single manufacturing step. The ISC process will replace the current multi-step manufacturing practice, which requires machining, forming, and joining of multiple components. Manufacture of cryogenic tank barrels using the ISC process will eliminate longitudinal welds, which reduces risk and costs associated with NDE

inspection, and reduce machining scrap from the current >90% to an estimated <5%, improving material efficiency and further reducing cost.

Potential Applications

Potential applications for the Integrally Stiffened Cylinder (ISC) manufacturing technology include launch vehicle structures such as cryogenic tank barrels, dry bay structures, and payload shrouds for vehicles from Sounding rockets and small satellite launchers to potentially SLS scale vehicles.