TDM’s 2015: The Year in Review

As 2015 cedes the floor to 2016, we asked the Technology Demonstration Mission projects to reflect on the year just past, briefly sharing with us their key milestones and successes.

Composites for Exploration Upper Stage: In 2015, the CEUS project—which seeks to advance innovative composite technologies to promote infusion of lightweight, affordable composites into future human-rated launch vehicles, spacecraft and large space structures—conducted a successful System Requirements Review and Key Decision Point B meeting. **Editor’s Note:** Key Decision Points throughout the NASA development life cycle provide decision-makers with regular junctures in which to review a project or program’s progress and recommend schedule adjustments; request further research or testing; or approve the next phase of development or implementation.

Also during 2015, the project established a composite-based, robotic manufacturing capability, featuring automated fiber placement, at NASA’s Marshall Space Flight Center and Langley Research Center; executed ...

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NASA’s Steve Jurczyk Oversees Annual Review

Steve Jurczyk, associate administrator for Space Technology Mission Directorate at NASA Headquarters in Washington, speaks to the assembled program and project managers and other Technology Demonstration Mission program personnel during the TDM Annual Review, held in November 2015 at NASA’s Marshall Space Flight Center. (Photo: NASA/Joel Kowsky)

As we enter the fifth year of the Technology Demonstration Missions Program, we celebrate the busy year just ended, a period of truly landmark achievement for so many of our projects, as evidenced in the cover story of this newsletter.

We’ve reached milestone after milestone, delivered hardware, passed reviews, resolved challenges, sent payloads soaring…and the best is still to come.

As busy and successful as 2015 was, 2016 promises to be even more exciting and challenging. It will be a year marked by great expectations, includ-

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procurements for composite prepreg materials, or those in which reinforcing fibers are pre-impregnated with a resin matrix, yielding unique properties when cured under high temperatures and high pressures; manufactured materials test coupons; and procured required manufacturing hardware.

**Deep Space Atomic Clock:** The DSAC project—which will fly and validate a miniaturized, ultra-precise, mercury-iron atomic clock that is orders of magnitude more stable than today’s best navigation clocks—continued advancing toward its 2016 test flight, completing its Critical Design Review and Key Decision Point D.

The project completed clock integration, functional and performance testing, vibration testing and thermal vacuum testing before being delivered for payload integration and testing in July 2015. During payload electromagnetic interference and electromagnetic compatibility testing, the flight clock’s ion tube experienced an anomaly and it was replaced with a flight spare.

The team resumed integration and testing in January, and the payload was delivered to the host spacecraft in February. In late 2016, following testing aboard the host spacecraft provided by Surrey Satellite Technologies U.S. of Englewood, Colorado, the DSAC payload will be lofted to space aboard a Space X Falcon 9 heavy booster, as part of the U.S. Air Force’s Space Test Program-2 mission. The DSAC project is led by NASA’s Jet Propulsion Laboratory.

**Evolvable Cryogenics:** The eCryo project—which is working to develop, integrate and validate cryogenic fluid management technologies for possible infusion into the Space Launch System stages design and future exploration systems—passed its Key Decision Point C in 2015, thus advancing from the formulation phase to the implementation phase.

The Small Multi-Purpose Research Facility in NASA Glenn’s Creek Road Cryogenics Complex lays the groundwork for the eCryo project, evaluating the performance of thermal protection systems required to provide long-term storage and transfer of cryogenic propellants in space. That work will help the project develop, integrate and validate cryogenic fluid management technologies for possible future flight vehicle infusion. (Photo: NASA/Bridget R. Caswell)

Now fully approved and operational, eCryo has completed initial testing in Integrated Vehicle Fluids, a collaborative effort with SLS Advanced Developments, which seeks new concept development focusing on propulsion systems, structures and materials supporting the evolved, 130-metric-ton-capacity version of SLS. A 20 Kelvin-to-90 Kelvin (-423 Fahrenheit to -297 Fahrenheit) calorimeter was built and currently is in use for testing of multi-layer insulation blanket and seams. An engineering development unit of the eCryo’s Radio Frequency Mass Gauge has been delivered for NASA’s Robotic Refueling Mission 3, a multi-phased International Space Station technology demonstration, overseen by NASA’s Goddard Space Flight Center, which tests tools, technologies and techniques to refuel and repair satellites in orbit. Flight hardware is on schedule for final delivery by mid-2016.

Finally, eCryo completed two studies and released final reports on both the Valve Seat Leak Test and the High Accuracy Delta-P Transducer. The project is led by NASA’s Glenn Research Center.

**Green Propellant Infusion Mission:** Milestone progress is being made to ready NASA’s GPIM project for launch in 2016. The spacecraft is designed to test on orbit the unique attributes of a high-performance, non-toxic, “green” propellant, a hydroxyl ammonium nitrate-based fuel/oxidizer mix known as AF-M315E. If successful, it could replace the highly toxic hydrazine and complex bi-propellant systems in use today, providing enhanced performance and volumetric efficiency.

In 2015, GPIM prime contractor Ball Aerospace & Technologies Corp. was able to integrate the green propellant propulsion subsystem less than two weeks after receiving it from provider Aerojet Rocketdyne. The propulsion subsystem will be the primary payload on the mission’s spacecraft, a Ball Configurable Platform 100 small satellite.

System performance and environmental testing have already begun, and launch to low-Earth orbit in partnership with the Air Force Space and Missile System Center is scheduled for later in 2016. Ball leads the project for NASA.
Laser Communication Relay Demonstration: The LCRD project continues to meet developmental milestones on its way to its 2019 flight test, where it will demonstrate bi-directional optical communications from geosynchronous orbit, using lasers to encode and transmit data significantly faster than today’s fastest radio-frequency systems, using comparable mass and power.

An artist’s rendering of the LCRD payload in operation in Earth orbit, demonstrating the revolutionary, high-speed delivery of data and video using laser encoding and transmission. (Image: NASA/GSFC)

In 2015, the modem lab was established and Ground Modem #1 successfully demonstrated bi-directional optical communication with the MIT-Lincoln Laboratory Optical Verification Testbed. The assembly of Ground Modem #2 also was completed.

Significant progress has been made in building flight optical assemblies at the vendor, and a number of flight hardware components have been delivered to NASA’s Goddard Space Flight Center for system integration. Goddard leads the LCRD project for NASA.

Low Density Supersonic Decelerators: The LDSD project continued to make progress in developing, testing and maturing new supersonic inflatable aerodynamic decelerators, or SIADs, and large supersonic ring sail parachutes, or SRSPs—intended to use atmospheric drag as a solution for planetary atmospheric deceleration to safely land crews, cargo and vehicles on Mars and other solar-system destinations.

The LDSD test vehicle hangs suspended beneath the static launch tower during a May 2015 dress rehearsal prior to its successful June 8 launch. (Photo: NASA/Bill Ingalls)

In 2015, the project conducted parachute design verification (PDV) tests of two, 30.5-meter-diameter SRSPs from two vendors, Pioneer and Airborne, and also conducted two SIAD design verification (SDV) rocket-sled tests of the Exploration-class SIAD-E. The SIAD-E was successful in its first test, but failed in its second. In both tests, the SIAD-E experienced oscillations after full inflation. The project’s efforts culminated in the second Supersonic Flight Dynamics Test in June, which demonstrated the Robotics-class SIAD-R and ballute technologies to Technology Readiness Level 6—demonstration of a system/subsystem model or prototype in a relevant environment—but the 30.5-meter ring sail parachute experienced a failure after achieving full inflation.

The project is in the process of compiling and documenting the results of the June flight test, the SIAD-R and ballute technology advancement report, the PDV test architecture and the SDV test architecture. The LDSD project is led by NASA’s Jet Propulsion Laboratory.

Solar Electric Propulsion: The SEP project is developing critical technologies to enable cost-effective access to destinations across the inner solar system, such as Mars and asteroids, and can support more affordable missions for commercial and government operations in Earth orbit. Using energy collected by large solar cell arrays that convert it to electrical power, an SEP system drives extremely fuel-efficient thrusters that provide gentle but continuous thrust throughout the mission—using 10 times less propellant than comparable, conventional chemical systems.

NASA and ATK Aerospace and Deployable Space Systems previously completed ground testing of large, high-power solar arrays capable of being stowed into small, lightweight packages for launch. One such concept already has been adopted for use on commercial satellites.

The SEP project’s Hall Effect Rocket with Magnetic Shielding Technology Development Unit, fabricated at NASA’s Glenn Research Center, undergoes testing in Glenn’s Vacuum Facility 5. (Photo: GRC/Michelle M. Murphy)

In 2015, the SEP team at NASA’s Glenn Research Center successfully tested a new 12.5-kilowatt Hall thruster throughout its full performance envelope. The magnetic shielding employed by this electric thruster will enable it to operate continuously for years—a critical capability for deep-space exploration missions. Glenn leads the SEP project for NASA.

NASA’s Marshall Space Flight Center manages the TDM program for NASA. All TDM projects are sponsored by NASA’s Space Technology Mission Directorate. Learn more about the program here.
Q&A: Meet GPIM Principal Investigator Chris McLean

By Ken Kesner

Chris McLean is a staff consultant at Ball Aerospace and Technologies Corp. in Boulder, Colorado, where he is also the principal investigator for NASA’s Green Propellant Infusion Mission. The GPIM project will demonstrate the practical capabilities of a hydroxyl ammonium nitrate–based fuel/oxidizer propellant blend, known as AF-M315E, developed by the U.S. Air Force Research Laboratory (AFRL) at Edwards Air Force Base in California. The fuel offers higher performance and is safer to handle and easier on the environment—“greener”—than traditional chemical fuels such as hydrazine, currently used in spacecraft thrusters. With fewer handling restrictions and potentially shorter launch processing times, the green propellant also could result in lowered costs.

Ball is the GPIM prime contractor, with team members including Aerojet Rocketdyne in Redmond, Washington; the AFRL; the Air Force Space and Missile Systems Center at Kirtland Air Force Base, New Mexico; and NASA’s Glenn Research Center, Goddard Space Flight Center and Kennedy Space Center.

McLean brings a wealth of propulsion and aerospace development experience to his position. He earned bachelor’s and master’s degrees in Science, Aerospace, Aeronautical and Astronautical/Space Engineering in 1989 and 1991, respectively, at the University of Washington. He was a project/engineer at Aerojet (formerly Rocket Research) from 1990-96, and was a lead development engineer in Aerojet’s Electric Propulsion Group, involved in the design, development and qualification of multiple hydrazine arcjet thruster systems.

McLean was a senior member of the technical staff at TRW from 1996-98, overseeing the design, development and fabrication of TRW’s electric propulsion test facility for the qualification of Hall Effect Thruster systems. During this tenure he successfully tested the first all-U.S. built Hall Effect Thruster subsystem, including a 3.0 kW thruster, power processor, and propellant feed system. He was a propulsion research engineering specialist at Pratt & Whitney from 1998-2004, supporting the US/Russian EXPRESS-M 4.5 kW Hall Effect Thruster flight experiment, and co-developed the T-220, T-140 and T-40 Hall Effect thrusters under various NASA and Air Force contracts. In addition to these efforts he led the development and flight qualification of the thrust vector control subsystems for the second and third stages of the Missile Defense Agency’s Ground-based Midcourse Defense system.

He joined Ball Aerospace in 2004, serving as program manager and PI for numerous advanced propulsion and green propellant programs in addition to GPIM, and was the lead systems engineer for Ball’s Robotic Lunar Exploration Program lunar lander program. The advanced propulsion work included collaborative study and design efforts to advance long-term storage and transfer of cryogenic propellant technologies for NASA, including the Orion Service Module and the Altair descent/ascent stages. Based on these efforts, United Launch Alliance funded Ball to develop multiple versions of its cryogenic orbital test bed (CRYOTE), and further contracts were awarded to Ball to support NASA’s Cryogenic Propellant Storage and Transfer (CPST) TDM studies, since renamed the eCryo project. McLean also facilitated Ball’s development of the LH2 fuel storage and delivery system that was flown in 2012 on Boeing’s Phantom Eye remote reconnaissance aircraft.

McLean spoke recently with The Bridge about progress on the GPIM mission and preparing for launch, which is scheduled for September. GPIM will be among a number of Department of Defense and other payloads that will launch from Cape Canaveral, Florida, during the second flight of the SpaceX Falcon Heavy. The launch is part of the Air Force’s Space Test Program 2 mission. STP-2 is scheduled to carry a second NASA Technology Demonstrations Mission payload, the Deep Space Atomic Clock.

2015 was a year of milestones for GPIM, including delivery and integration of the green propellant propulsion subsystem onto the spacecraft. What struck you most in the past year?

I can’t say enough about the GPIM team. The principal and co-investigator team we constructed includes Ball Aerospace, Aerojet, AFRL Edwards, AF SMC, NASA Goddard, Glenn, Kennedy—a nationwide team that has shaped and supported this program.

Early in the year we faced some significant technical challenges with the payload, specifically the removal of the 22 N thruster due to development challenges that were inconsistent with the project’s cost and schedule constraints. The team worked hard to resolve those issues and constructed a successful flight configuration, replacing the 22 N thruster with a fifth 1 N thruster, meeting all but one of the original TDM office project goals. After that decision was made, the flight payload was completed at Aerojet and delivered to Ball Aerospace. The propulsion subsystem was integrated onto the Ball BCP-100 spacecraft in just a handful of days after delivery in September. Environmental testing was completed ahead of schedule in January 2016.
How has that positioned you for the months ahead, leading up to launch?

We’re right where we need to be. There have been multiple launch delays that provided extra padding in the original program schedule—as it did for the other spacecraft that will be launched on STP-2. Things are marching along at an excellent pre-launch cadence right now and I’m very happy with it all.

What are your primary challenges now?

The major technical challenges were with the new AF-M315E thrusters; these issues are behind us now. With the spacecraft work nearly finished—in February we’ll button up the spacecraft and put it in storage for a couple of months—we’re focusing on the propellant loading campaign. AF-M315E is a brand-new fuel, with unique properties compared to heritage propellants. AFRL developed new propellant loading carts and procedures that we’ve peer-reviewed with NASA, industry and the Department of Defense. We’re looking forward to working with the range safety folks to help that happen.

After all the effort to this point, how does it feel to see the launch on the horizon; to obtain the information needed to move forward with this green fuel?

That’s a really good question. I’ve been doing this for 25 years; this is the fifth time I’ve been involved in the flight implementation of an advanced, in-space propulsion technology. It’s nice to see a resurgence of U.S. interest in the flight demonstration of new propulsion technologies. The propulsion community is very pleased to have the opportunity to demonstrate this technology on orbit, and we really appreciate NASA’s backing, support and working with us for a successful program.

The implementation of every new technology has its challenges, but I think we’ve beaten that down significantly. We’re at the point where the fuel is recognized as a serious option with significant benefits, not only in safety but also in performance on orbit. It’s a great opportunity to do this mission and push this technology.

Assuming all goes as planned, what comes next?

I think the overall goal is that, once we’ve flown this propellant and thruster technology, people will consider its benefits and suitability for their future missions. We’re using it in some proposals now, trying to find the right fit. I believe there are applications for this fuel in the defense community that will take advantage of our work prior to some of the NASA or commercial applications.

There are always going to be places where hydrazine fuel makes sense. That’s exactly why, early in the program, we funded a mission design study at NASA Glenn’s COMPASS (COllaborative Modeling for Parametric Assessment of Space Systems) mission design center to evaluate what missions AF-M315E enables. After GPIM, when we plan missions where this fuel has the potential for significant payoff, we’ll be able to say, “Okay, that’s something we’ve demonstrated on orbit already. Let’s take advantage of these improvements for our mission.”

Kesner, an ASRC Federal/Analytical Services employee, supports Marshall’s Office of Strategic Analysis & Communications.

An artist’s rendering of the Green Propellant Infusion Mission payload in flight aboard the Ball BCP-100 spacecraft. (Image: Ball Aerospace)

http://www.nasa.gov/mission_pages/tdm/main
Taking a Look Back at TDM in 2015…continued from p. 1

ing flight tests for two of our projects: the Deep Space Atomic Clock and the Green Propellant Infusion Mission. These projects, led by stellar teams that include workers across the nation, exemplify the TDM spirit, the continuing challenge to seek new solutions to old spacefaring problems, new ways to span the gulf between scientific and engineering obstacles and the revolutionary technologies needed to overcome them.

I can’t fully express my pride in these teams—in all the men and women who make up our program—in the brief space I’m allotted here, but I hope they know how deeply I appreciate their commitment to their endeavors and to the cause of NASA’s Space Technology Mission Directorate, our sponsor.

I am confident that in the years to come, as we take bold new strides in deep-space navigation and planetary entry and descent, in environmentally friendly fuels and solar electric-powered ships to the stars, in composites and cryotechnologies and space communications, TDM will be remembered as the team that charted the course.

Thanks, and let’s have another year to remember in 2016.

Gagliano manages the TDM Program Office at Marshall.

NASA Public-Private Partnerships Leading to New TDM Projects

NASA’s Space Technology Mission Directorate has selected partnerships with 22 U.S. companies to advance the agency’s goals for robotic and human exploration of the solar system by shepherding the development of critical space technologies.

Four of the partnerships, which were announced in November, are to become part of STMD’s suite of Technology Demonstration Mission projects, managed at NASA’s Marshall Space Flight Center.

“Our aim is to work with these companies over the next two years to mature their technologies to a level where they are ready for flight demonstrations,” said Danny Harris, deputy manager of the TDM program office at Marshall.

Through the “Utilizing Public–Private Partnerships to Advance Tipping Point Technologies” solicitation, STMD selected nine companies to mature technologies beyond their “tipping point” with the goal of enabling private industry to develop and qualify them for market. That work will stimulate the commercial space industry while delivering technologies and capabilities needed for future NASA missions and commercial applications.

Three companies in the solicitation are pursuing projects involving “Robotic In-Space Manufacturing and Assembly of Spacecraft and Space Structures.” The three projects are to become part of the TDM portfolio:

• Public-Private Partnership for Robotic In-Space Manufacturing and Assembly of Spacecraft and Space Structures—Orbital ATK, Dulles, Virginia
• Versatile In-Space Robotic Precision Manufacturing and Assembly System—Made in Space Inc., Moffett Field, California
• Dragonfly: On-Orbit Robotic Installation and Reconfiguration of Large Solid RF Reflectors—Space Systems Loral, Palo Alto, California

STMD will determine in the spring of 2016 how these fixed-price projects, which are all in the $20 million price range, fit into the TDM portfolio, Harris said. Each has an approximate two-year performance period, culminating in a system-level demonstration of the technology.

NASA also secured partnerships with 13 companies through the Announcement of Collaborative Opportunity (ACO) solicitation, “Utilizing Public-Private Partnerships to Advance Emerging Space Technology System Capabilities.” Through these partnerships, NASA provides technical expertise and test facilities to help industry partners mature key space technologies. The awards will result in Non-Reimbursable Space Act Agreements between the selected companies and NASA.

One of these partnerships, “GR-1 Aerojet Rocketdyne Glenn Goddard (ARGG) Collaboration,” also is slated to become part of the TDM portfolio. Led by Aerojet Rocketdyne Inc. of Redmond, Washington, the partnership seeks to qualify new green propellant thruster technologies. NASA’s Glenn Research Center and NASA’s Goddard Space Flight Center are partners in the effort, which will complement TDM’s current Green Propellant Infusion Mission project.

“These new partnerships between NASA and U.S. industry can accelerate the development and infusion of these emerging space system capabilities,” said Steve Jurczyk, associate administrator for STMD at NASA Headquarters in Washington. “Sustained technology investments must be made to mature the capabilities required to reach the challenging destinations and meet the agency’s exploration goals, such as our journey to Mars.”
Bridge Builder: Eric Burt Puts Deep-Space Timekeeping to the Test

Editor’s Note: TDM Bridge Builders are team members at NASA centers and partner organizations who are helping bridge the gap, bringing one of our cutting-edge technologies to flight readiness. Got a suggestion for a TDM teammate worthy of the spotlight? Email richard.l.smith@nasa.gov.

Eric Burt is an atomic clock technologist for the Deep Space Atomic Clock project at NASA’s Jet Propulsion Laboratory. In addition to his role on the DSAC project, he is a senior member of JPL’s technical staff, conducting research tied to the development of ultra-stable atomic clocks for space-based and ground-based applications. He has extensive background in trapping and laser-cooling ions and neutral atoms—critical experience for the development of highly accurate atomic clocks. Todd Ely, DSAC project scientist at JPL, called Burt “the guy behind the scenes, generating the magic to get the disparate DSAC elements to work together as an integrated, stable clock.”

A native of Berkeley, California, Burt is a graduate of the University of Michigan in Ann Arbor, where in 1979 he received a bachelor’s degree in mathematics. He also holds a master’s degree and a doctorate in physics from the University of Washington in Seattle, earned in 1990 and 1995, respectively. From 1995 to 1997, he was a postdoctoral fellow at the University of Colorado in Boulder, working with Carl Wieman and Eric Cornell on experiments with Bose-Einstein condensates. He worked at the U.S. Naval Observatory in Washington from 1997 to 2001, developing a laser-cooled cesium fountain atomic clock, and joined NASA and JPL in 2001. He is an active member of the American Physical Society and the Institute of Electrical and Electronics Engineers.

Burt spoke with The Bridge about his role in DSAC and his tenure at JPL.

What are your responsibilities on the DSAC project? What else do you do at JPL?

I’m leading the effort to bring the instrument up to an operational state. This effort has been divided into four areas. First, because this is a first-of-its-kind technology demonstration, we perform experiments to clarify our preparatory procedures and to improve quantitative measures for determining our level of preparedness. Second, I am responsible for demonstrating that the instrument can reach its performance requirements. To this end, we have evolved a set of tests that automatically and efficiently probe the main functions of the instrument governing its performance. These tests have been very useful as a debugging tool as well. Third, as is typical for a technology demonstration project, there have been several unexpected issues that have come up, and it has been primarily my job to characterize these issues, determine the root cause and recommend the action needed to reach a resolution. Fourth, the development of control algorithms has been carried out in parallel with all three previous areas. As we’ve learned more about how the instrument responds, I’ve helped guide the definition of these algorithms.

I’ve been an atomic clock technologist for most of my JPL career, carrying out research projects on the development of ultra-stable clocks for a variety of applications. I also have a strong interest in pursuing basic fundamental physics questions, and atomic clocks often can be used to address these.

How do you hope DSAC will impact NASA’s TDM goals?

In addition to successfully demonstrating the operation of this instrument in space, one of the key objectives of our work is to determine how to run a successful Technology Demonstration Mission. Particularly, we’re documenting the differences between how we’ve approached this work as compared to other flight projects in which the instrument technology is more mature.

What do you hope most to accomplish on DSAC? What outcome are you most excited to see?

It will be very exciting to see the instrument operate in space, but following close behind that is the desire to see the technology incorporated into other missions. There are already several initiatives heading in this direction. (Editor’s note: We hope to be able to share more information in future issues as those initiatives become official flight projects.) Also, the DSAC project was able to bring a large number of resources to bear on hardening this technology, or making it more resilient to the harsh space environment. In some cases, we will be able to transfer progress made to our research clocks, enabling them to work better as well.

Tell us about your first NASA job.

Initially, I worked on the Primary Atomic Reference Clock in Space project, or PARCS, a laser-cooled, cesium atomic clock designed to be flown on the International Space Station in 2008. It was defunded but helped pave the way for other advances in space-based timekeeping, including DSAC.
What's one thing most people would be surprised to learn about you?

I’m an outdoor enthusiast. I ran track in high school and college, and loved long-distance trail running. This evolved into hiking, which in turn evolved into climbing. I’ve climbed internationally in Australia, Bolivia, Canada and Peru, and I’m very fortunate to live only a few hours’ drive from one of the most beautiful mountain ranges in the world, the high Sierra. Initially, I learned to climb simply as a means to get to places otherwise inaccessible to hiking. But the more I did it, the more I started to like it for its own sake. I’ve done all types: rock climbing, ice climbing and mountaineering, which is a combination of the first two, set in the high mountains. The highest point I’ve climbed to is the 20,000-foot Huayna Potosi peak in Bolivia.