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in review

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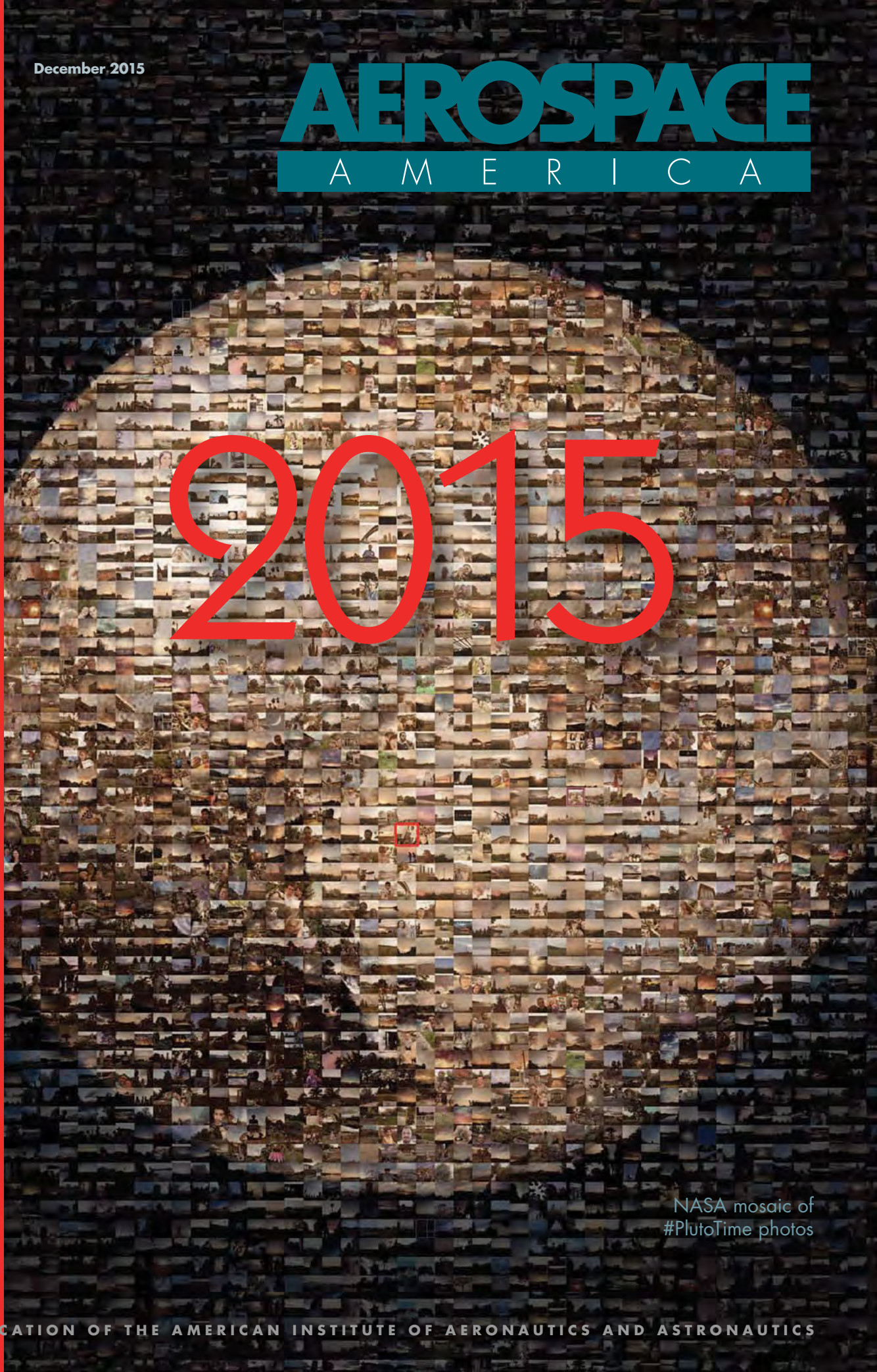

NASA mosaic of #PlutoTime photos

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Four Magnetospheric Multiscale mission spacecraft developed and tested at NASA's Goddard Space Flight Center in Maryland were launched on an Atlas-Centaur AV-53 in March. The mission will study how the sun's and the Earth's magnetic fields connect and disconnect, which transfers energy between the magnetic fields causing **space weather** that affects terrestrial technologies such as GPS networks and energy grids.

The mission reached an important milestone in July, when the MMS began executing maneuvers to begin formation flying. The spacecraft will fly in a tetrahedral formation to observe electrical and magnetic fields in three dimensions with a goal of understanding and predicting disruptive space weather events. Small and large formation maneuvers are maintained through onboard closed-loop maneuver control using an attitude control system with 12 thrusters on each spacecraft. Attitude sensor data is provided by star and sun sensors.

The **Bell 525 Relentless**, the world's first commercial fly-by-wire helicopter, made its initial flight in Amarillo, Texas, in July. The fly-by-wire technology replaces traditional manual flight controls with a digital interface that provides improved situational awareness and mission control to the pilot. Pilot inputs are transmitted to the flight control computer, which translates those inputs into roll, pitch, and yaw and lateral and vertical guidance and control. Among other things, the test flight demonstrated taxi maneuvers, hover maneuvers and low-speed handling qualities in winds gusts up to 20 knots.

The European Space Agency's **LISA Pathfinder** was set to launch in December to test low-frequency gravitational wave detection. The mission, which will be conducted in collaboration with NASA Jet Propulsion Laboratory, will put two test masses in a near-perfect gravitational free fall, and control and measure their motion with unprecedented accuracy. This will be done with inertial sensors, a laser metrology system, a drag-free control system and an ultra-precise micro-propulsion system.

SpaceX made two attempts to land a spent Falcon 9 first stage on a custom-built ocean platform, which would be a stride toward reusability and the ultimate goal of returning the first stage to dry land. An attempt in January failed after the stabilizing fins exhausted their fuel supply prematurely.

An attempt in April ended when the first stage made a hard landing on the platform and tipped over on the deck. The Falcon 9 first stage is 14 stories tall and reaches speeds of up to 1,300 meters per second. A series of three burns must be executed to stabilize and slow the descent to 2 meters per second. The limited size of the ocean platform requires a landing precision of 10 meters. Previous landing tests in the ocean only showed precisions of 10 kilometers; therefore, four hypersonic fins, each controlled independently, were added to the first stage and are deployed on descent to control the direction of the lift vector.

As the cost of high-performing sensors keeps dropping, complex sensing applications are becoming more available. For example, the Low Cost Surface Awareness, LCSA, system is an affordable approach to providing enhanced situational awareness of an airport's surface operations to tower controllers and air traffic managers. While high-functioning radar systems have been installed at busy airports around the country, they cost $10 million to $25 million, out of price range and unaffordable for many smaller airports. The LCSA system uses above-ground magnetic or infrared sensors to determine when a block, a subdivided operationally-relevant segment of a runway or taxiway, is occupied. The status of the various blocks is displayed to air traffic controllers to supplement visual information and provide safety alerts when another aircraft is detected to be entering an occupied space. This system was tested during August at Teterboro Airport in New Jersey.

Forecasting disruptive space weather

by Lesley A. Weitz and Luisella Giulicchi

*The **Guidance, Navigation and Control Technical Committee** advances techniques, devices, and systems for guiding and commanding flight vehicles.*

European Space Agency

The European Space Agency's LISA Pathfinder was readied for launch in Germany in September before departing for the launch site in French Guiana.