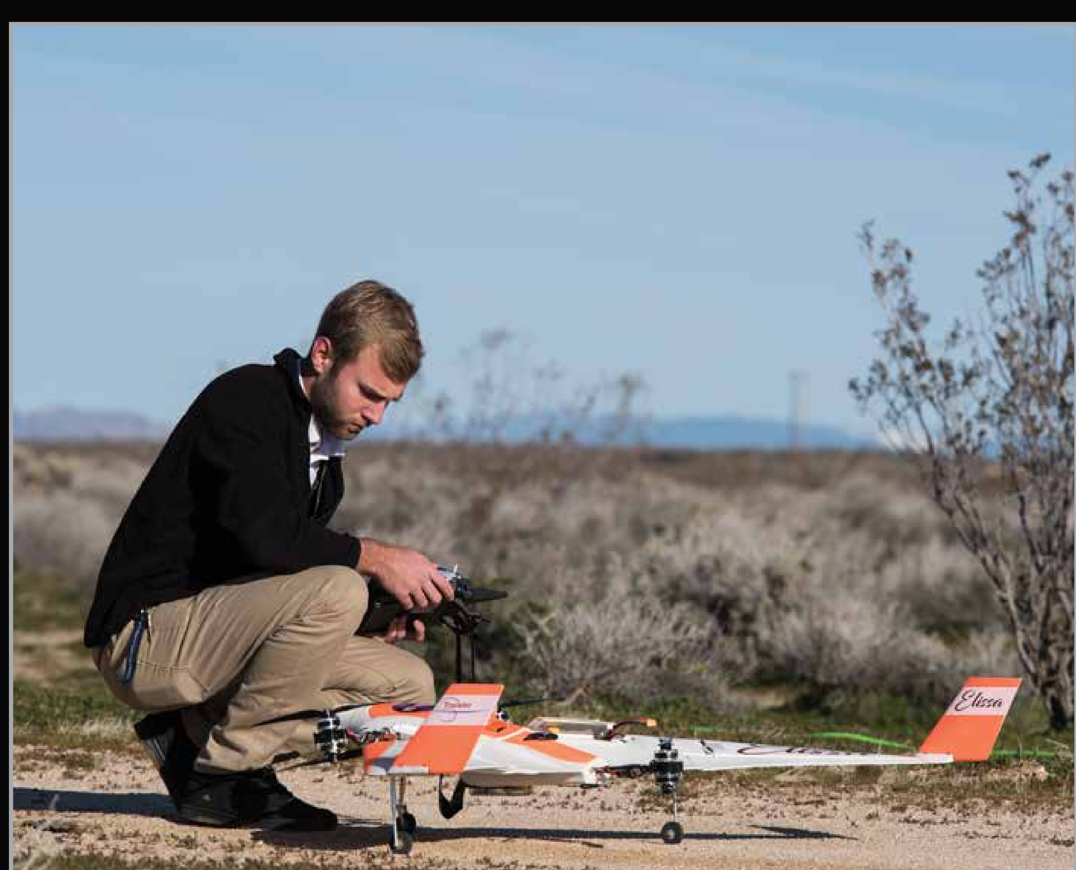
National Aeronautics and Space Administration

NASA

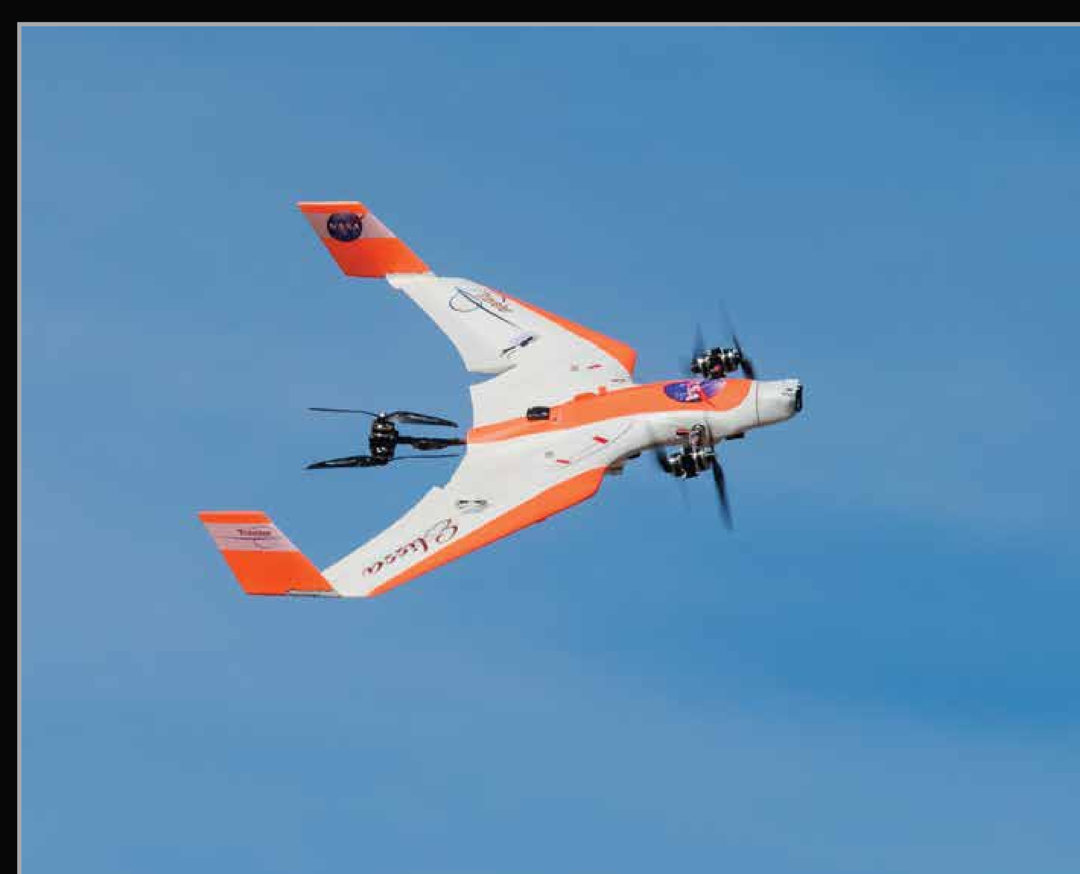
What's Happening @Armstrong

April 2017

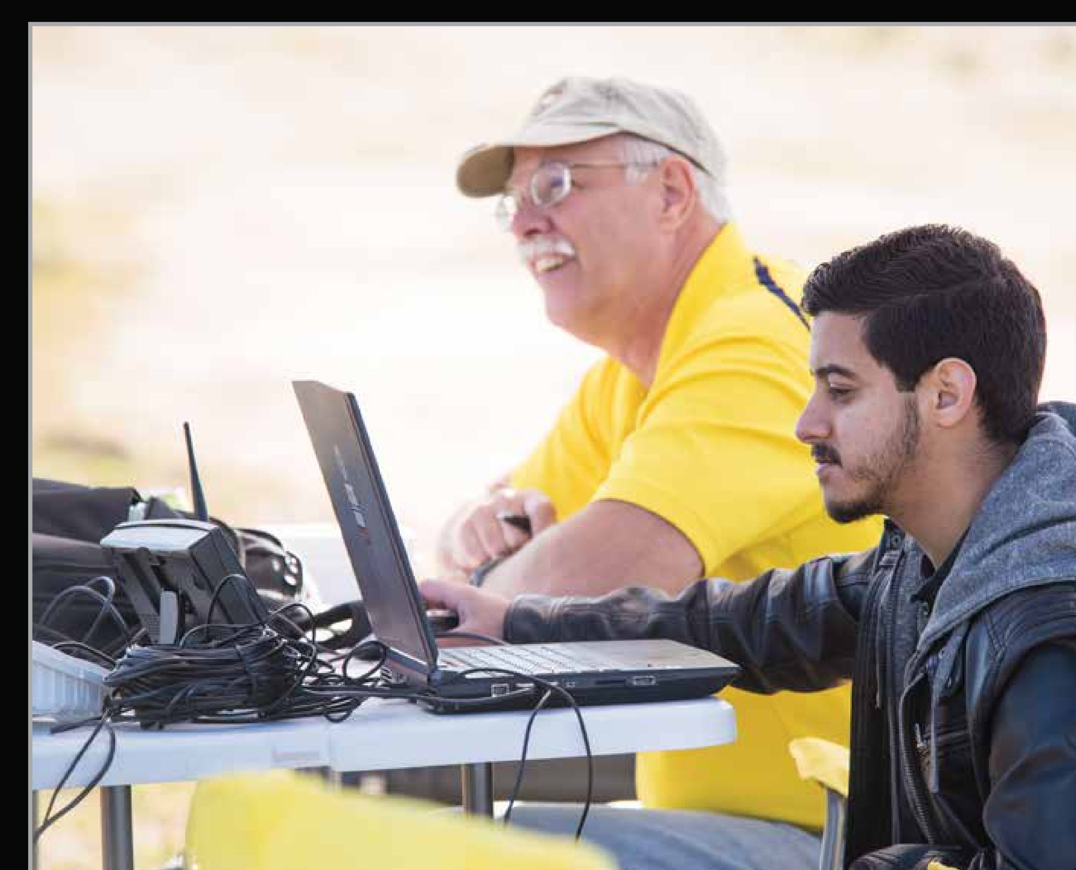
TECHNOLOGIES IN DEVELOPMENT.



Jacobs Technology Inc. safety pilot Alex Flock pre-flights Elissa, NASA Armstrong's autonomy testbed.



NASA Armstrong's autonomy testbed Elissa is shown in flight during testing in March 2017.



Jacobs Technology Inc. operations engineer Jan Scofield and ground control operator Luke Guirguis conduct flight testing.

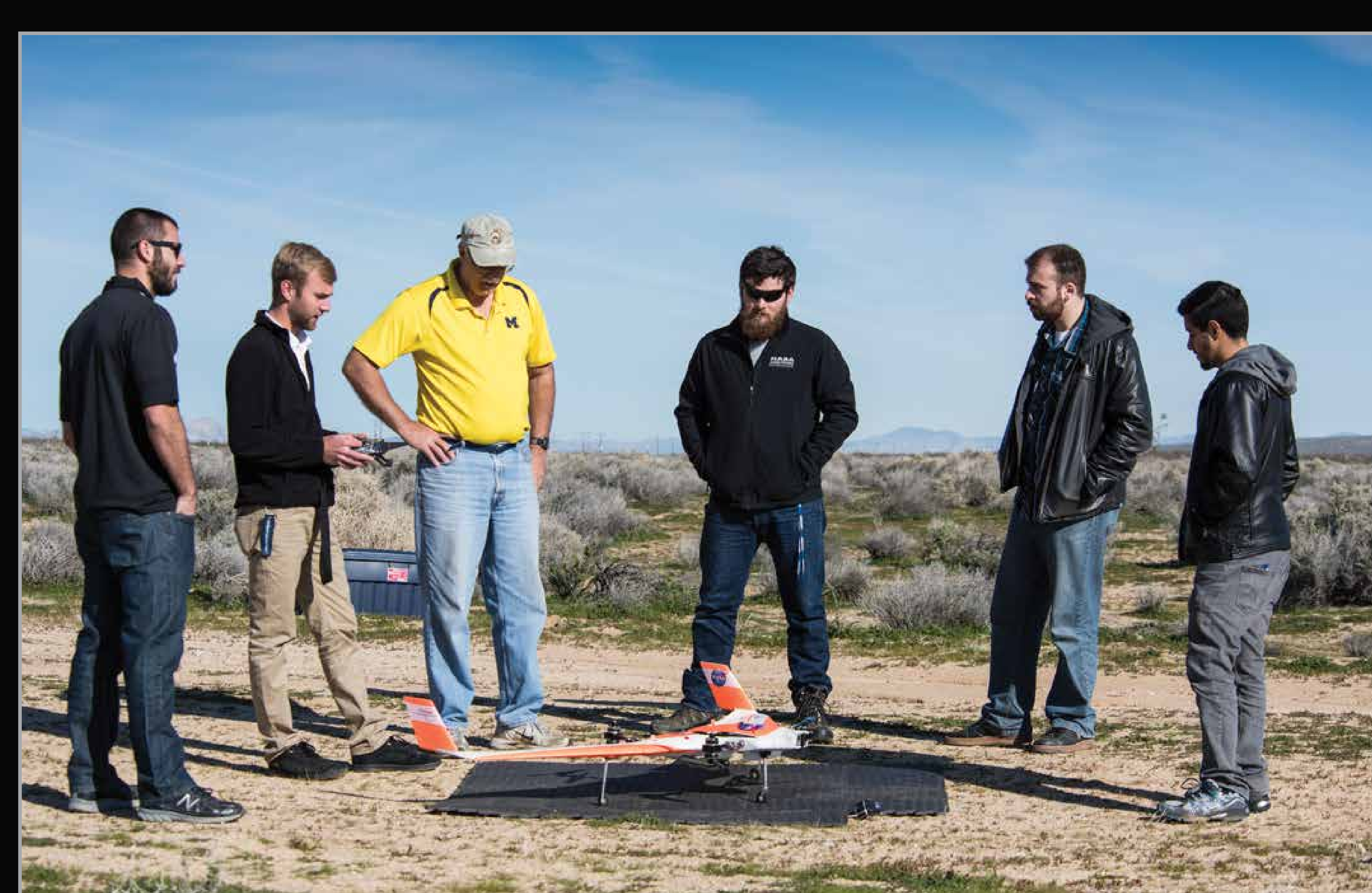
NASA Armstrong Photos / Lauren Hughes

Trustworthy Autonomy

Verifying a Highly Autonomous Unmanned Aircraft System (UAS)

Objective: Develop methodology to certify unmanned and autonomous systems using an open source Expandable Variable Autonomy Architecture (EVAA) software testbed and a multi-monitor run-time assurance algorithm (MM-RTA) to address flight safety for an autonomous aircraft executing real-world missions

End goal is to enable beyond visual line of sight (BVLOS) and linkless operations



Autonomy test team gathers around Elissa to discuss its next flight test. From right, Jeff Sutherland, Alex Flock, Jan Scofield, Cameron Law, Ashraf Al-Hajjeh, and Luke Guirguis. Using a modified commercial BirdsEyeView Aerobotics FireFLY6 UAS, the team is developing and testing a software method for safely bounding the behavior of an autonomous aircraft in support of Federal Aviation Administration (FAA) and American Society for Testing and Materials International (ASTM) regulatory development. *NASA Armstrong Photo/Lauren Hughes*

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The Traveler Effort

Trustworthy Autonomy

Autonomy is a cross-cutting technology requiring a high degree of integration. As such, it must, to a large degree, be approached holistically. The Traveler effort approaches autonomy from this perspective.

The definition of autonomy for the purposes of this effort will be automatic decision making.

At the heart of the holistic approach is the premise that the conduct of any safe flight operation follows certain fundamental rules:

1) The rules that govern safe and appropriate flight conduct remain unchanged to any reasonable mission that is to be conducted by any particular type of aircraft for a given airspace or concept of operations (ConOps)
2) The rules of safety and appropriate flight must always out prioritize mission conduct
3) The rules of safe and appropriate flight can be functionally decomposed, and once decomposed are to a large degree independent from one another
4) When these individual rules are applied to specific situations in flight, they carry different levels of consequences if not followed

To instantiate this premise, the Traveler effort has constructed a software framework that leverages run-time assurance (RTA) methods to assure safe operations. However, unlike previous RTA efforts, Traveler is developing an RTA architecture that monitors multiple functional areas simultaneously (termed a multi-monitor RTA or MM-RTA). MM-RTA coordinates the different functional areas with risk-based logic. This framework which the Traveler effort is calling the expandable variable-autonomy architecture (EVAA), is intended to be a software testbed for MM-RTA research. This approach uses MM-RTA methods to safely bound autonomous behavior, and thus relieves the requirement to certify the guidance logic for accomplishing the mission objective. Furthermore, EVAA is structured to allow the addition and removal of monitors, sensors and aircraft models with a minimum of V&V requirements. Thus, the EVAA framework should support any given ConOps on any given aircraft with a minimum of software tailoring and associated V&V.

Safety assurance must be validated. To accomplish this, the Traveler effort heavily leverages flight-testing. Although simulation and analysis are used, the complex environmental situations that safety assurance must be proven under are not yet modelled well within simulations. Therefore, Traveler testing quickly moves to flight-testing during development. This use of flight-testing allows the tested system to be validated, and identifies simulation requirements and model improvements to assist future evaluations.

The Traveler effort is executing a phased development and evaluation of EVAA. These phases are as follows:

1) Formulate initial requirements focusing on
    a. Monitor control coordination for an MM-RTA
    b. Interface requirements for an MM-RTA
2) Finalize development of an MM-RTA
    a. Identify sensor requirements
    b. Identify monitor requirements for a given ConOps
    c. Establish the methodology for making and airworthiness case
3) Validate the MM-RTA findings
    a. Apply EVAA to 3 different aircraft and ConOps
    b. Successfully gain flight approval by making an airworthiness case based on the performance of an MM-RTA

The Traveler effort is closely working with both the FAA and industry regarding EVAA development and evaluation. Findings from each phase are shared with the FAA to aid in their development of certification standards for autonomous aircraft.