

NASA/TM—2018-219759



# Aeronautics Autonomy Testbed Capability (AATC) Team Developed Concepts

*Phillip J. Smith*  
*Glenn Research Center, Cleveland, Ohio*

## NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI Program provides access to the NASA Technical Report Server—Registered (NTRS Reg) and NASA Technical Report Server—Public (NTRS) thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counter-part of peer-reviewed formal professional papers, but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., “quick-release” reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at <http://www.sti.nasa.gov>
- E-mail your question to [help@sti.nasa.gov](mailto:help@sti.nasa.gov)
- Fax your question to the NASA STI Information Desk at 757-864-6500
- Telephone the NASA STI Information Desk at 757-864-9658
- Write to:  
NASA STI Program  
Mail Stop 148  
NASA Langley Research Center  
Hampton, VA 23681-2199

NASA/TM—2018-219759



# Aeronautics Autonomy Testbed Capability (AATC) Team Developed Concepts

*Phillip J. Smith*  
*Glenn Research Center, Cleveland, Ohio*

National Aeronautics and  
Space Administration

Glenn Research Center  
Cleveland, Ohio 44135

---

April 2018

## Acknowledgments

The author would like to thank all members of the Aeronautics Autonomy Testbed Capability team especially Casey Bakula and Raymond Castner of Glenn Research Center and Robert McSwain of Langley Research Center. The entire team is responsible for creation of all of the concepts and figures presented in this report.

Trade names and trademarks are used in this report for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

*Level of Review:* This material has been technically reviewed by technical management.

Available from

NASA STI Program  
Mail Stop 148  
NASA Langley Research Center  
Hampton, VA 23681-2199

National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
703-605-6000

This report is available in electronic form at <http://www.sti.nasa.gov/> and <http://ntrs.nasa.gov/>

# **Aeronautics Autonomy Testbed Capability (AATC) Team Developed Concepts**

Phillip J. Smith  
National Aeronautics and Space Administration  
Glenn Research Center  
Cleveland, Ohio 44135

## **Summary**

In 2015, NASA formed a multicenter, interdisciplinary team of engineers from three different aeronautics research centers who were tasked with improving NASA autonomy research capabilities. This group was subsequently named the Aeronautics Autonomy Testbed Capability (AATC) team. To aid in confronting the autonomy research directive, NASA contracted IDEO, a design firm, to provide consultants and guides to educate NASA engineers in the practice of design thinking, which is an unconventional method for aerospace design processes. The team then began learning about autonomy research challenges by conducting interviews with a diverse group of researchers and pilots, military personnel and civilians, and experts and amateurs.

Part of this design thinking process involved developing ideas for products or programs known as concepts that could enable real-world fulfillment of the most important latent needs identified through analysis of the interviews. The concepts are intended to be sacrificial, intermediate steps in the design thinking process and are presented in this report to record the efforts of the AATC group. Descriptions are provided in present tense to allow for further ideation and imagining the concept as reality as was attempted during the team's discussions and interviews. This does not indicate that the concepts are actually in practice within NASA, though similar programs may exist independent of AATC.

These concepts were primarily created at two distinct stages during the design thinking process. After the initial interviews, there was a workshop for concept development, and the resulting ideas are shown in this work as derived from the First Round. As part of succeeding interviews, the team members presented the First Round concepts to refine the understanding of existing research needs. This knowledge was then used to generate an additional set of concepts denoted as the Second Round.

Some concepts were created by a single person in a few minutes while others were refined by the entire team over several weeks. Thus, certain ideas are more detailed than others, but those from the Second Round are not necessarily more comprehensive than the First Round concepts. Primarily, as reported here in the Second Round section, the designs serve to encompass more of the high-level end-user research needs that were not necessarily known to the team during the prior workshop. In the figures provided throughout this report, illustrations are often provided to represent a concept. Nearly all of the images are informal sketches or renderings, and this casualness should, hopefully, not be held to negate the potential insights available within the concepts.

It is expected that the reader will form his or her own comments on the merits of various concepts. Positives and negatives are occasionally discussed but otherwise left unwritten in favor of simply describing the concept and what is hoped to be accomplished. Again, these are intermediary constructs and shortcomings are indeed present in the proposals. In practice, concepts were often temporarily combined or split to better understand and match identified autonomy research needs. For further detailed information on the work process and the final concept design, please see the summary by McGowan, Bakula, and Castner (Ref. 1).

## Nomenclature

AATC	Aeronautics Autonomy Testbed Capability
ATM	Air Traffic Management
DARPA	Defense Advanced Research Projects Agency
FAA	Federal Aviation Administration
HIL	hardware integration lab
HW	hardware
ISS	International Space Station
NAS	National Aerospace System
SIM	simulation
sUAS	small unmanned aerial system
SW	software
TRL	technology readiness level
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
USB	Universal Serial Bus

# First Round

## Autonomy Happy Hour

This concept (Figure 1) is a NASA-hosted social media website structured to suit the interests of the civil servant workforce. These interests are organized by users and may or may not be project oriented. Some groups share only written posts while others schedule teleconferences or even in-person meetings to address the group's primary interests. This tool allows NASA engineers, management, and potential external partners to connect with the appropriate people regarding specific areas of expertise. It offers workers a place to discuss and transfer capability as well as identified needs and serves as a tool for quickly staffing projects by aligning project needs with those who have the required skill and availability.

By bringing together compatible employees for problem sharing and solving, Autonomy Happy Hour increases the probability of researchers attaching to projects that align with the work they enjoy, thus likely improving project outcomes. It encourages intercenter collaboration and external partnerships. The identified downsides include the following: a perceived subversion of management, who then may not support their employees' participation, and a low level of employee contribution, due to scheduling constraints, existing workload, and concern over obligatory involvement. It may also remain necessary for there to be a moderator to encourage useful and relevant content.

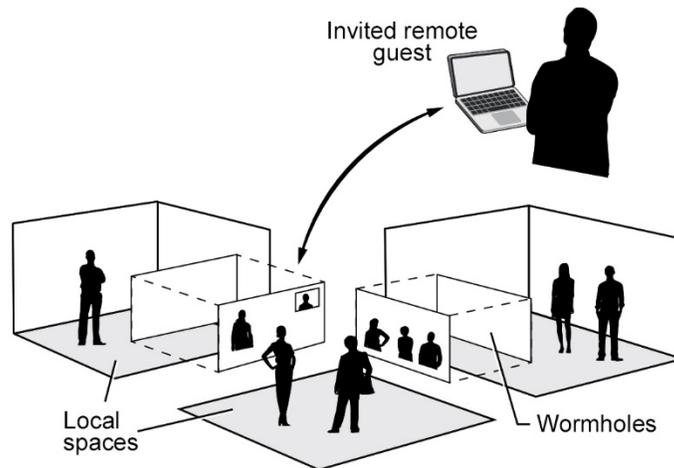


Figure 1.—Autonomy Happy Hour concept.

## Autonomy Freelancer

Autonomy Freelancer (Figure 2) is an online community where people or organizations post autonomy problems for which they need solutions. This operates similarly to Slack, an existing online categorized community designed to promote team communication. All categories on this site relate primarily to current aeronautics autonomy issues. Problems are viewed by a solutions providing community as organized and uniformly formatted problem submissions. These users can propose work on posted problems where funding is attached. Review and reward procedures enable NASA to recognize potential problem resolutions with the most impact and then recognize people who successfully develop and provide solutions.

This concept supports identification of the right problems, which are those that are truly holding back deployment of autonomous technologies. It develops a community to solve those problems by highlighting who is leading the work on such issues. This web-based community encourages collaboration and allows NASA to match or even accelerate the pace of autonomy research.

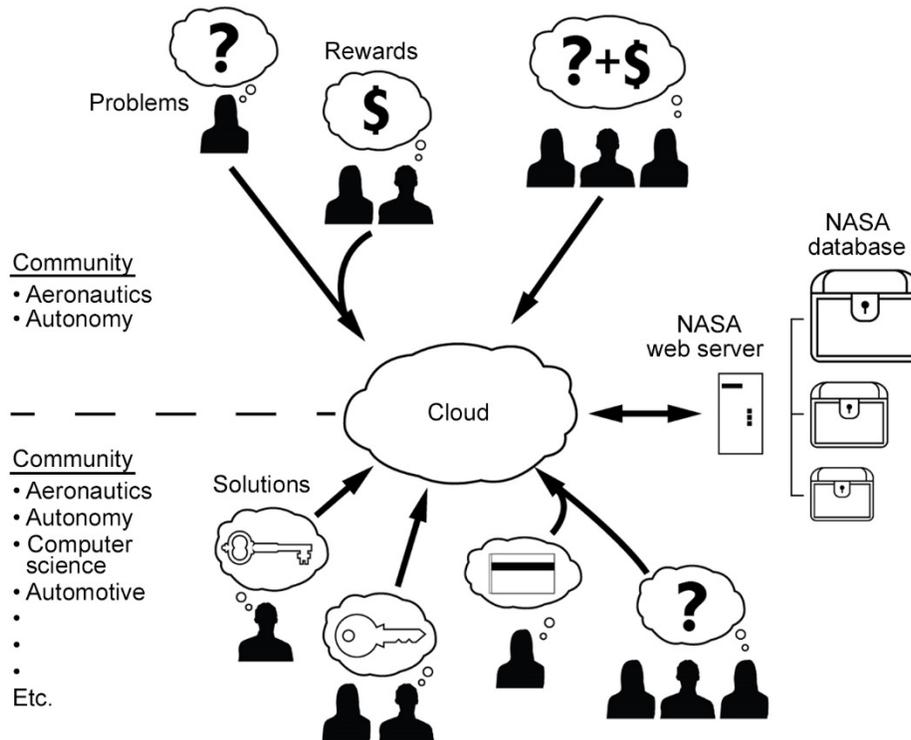


Figure 2.—Autonomy Freelancer concept.

## Fast National Aerospace System (NAS)

The Fast National Aerospace System (NAS) concept (Figure 3) provides a form of testbed construction set to standardize interfaces, thus simplifying access to unique NASA flight test resources. It is critical to provide pathways for engineers to integrate laboratory-level technologies into larger scale test platforms. These more capable experimental aircraft allow access to various classes of airspace within the NAS.

By providing interaction opportunities with NASA aircraft and establishing real flight scenarios for universities, startup companies, and other Federal research centers, NASA establishes a program to develop high technology readiness level (TRL) autonomy products from low TRL ones. This supports high utilization of existing NASA testbeds and expands capabilities available to many researchers.

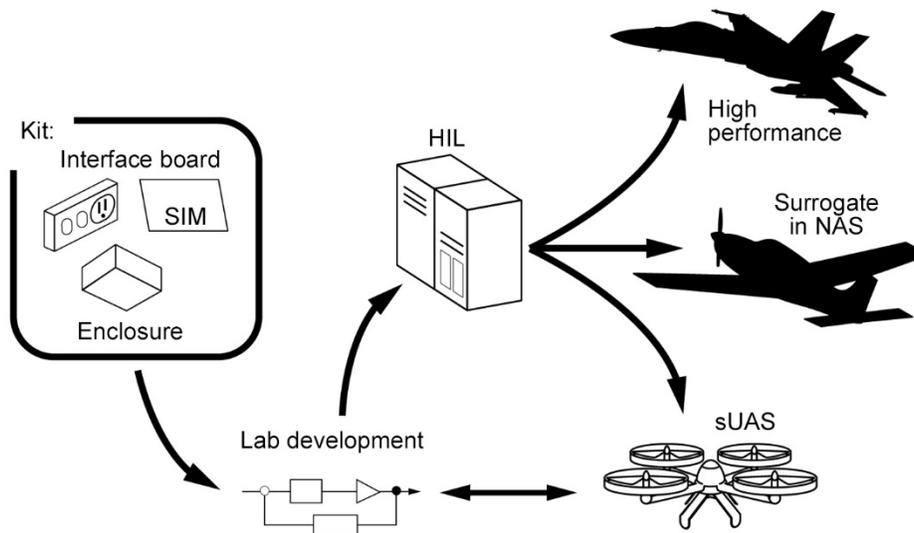


Figure 3.—Fast National Aerospace System (NAS) concept. HIL, hardware integration lab; SIM, simulation; sUAS, small unmanned aerial system.

## Never Stop Interviewing

Since the Aeronautics Autonomy Testbed Capability (AATC) team obtained large quantities of useful information through interviewing, it is suggested in the Never Stop Interviewing concept (Figure 4) that NASA prolong the learning by continually recreating the interview process employed in this project to solicit periodic feedback from external partners in autonomy research. By doing so, an organization such as NASA affirms the Agency is directing funding towards the most significant autonomy issues. This allows NASA to sustain an awareness of the needs, concerns, and state-of-the-art knowledge among the personnel in the aerospace autonomy field. NASA is then able to more frequently evaluate the connection of established strategic goals with the obstacles identified by the greater research community.

The concept accentuates NASA as an active and binding participant in this research community. It is a major challenge, however, to accurately identify and update the complete pool of stakeholder candidates. Additionally, processing and communicating the feedback is highly time intensive. It is likely to require dedicated teams for this work rather than sporadic, uncoordinated interviews. A final concern exists in overutilizing popular and busy interviewees who then will not make themselves available for future uncompensated consultation.

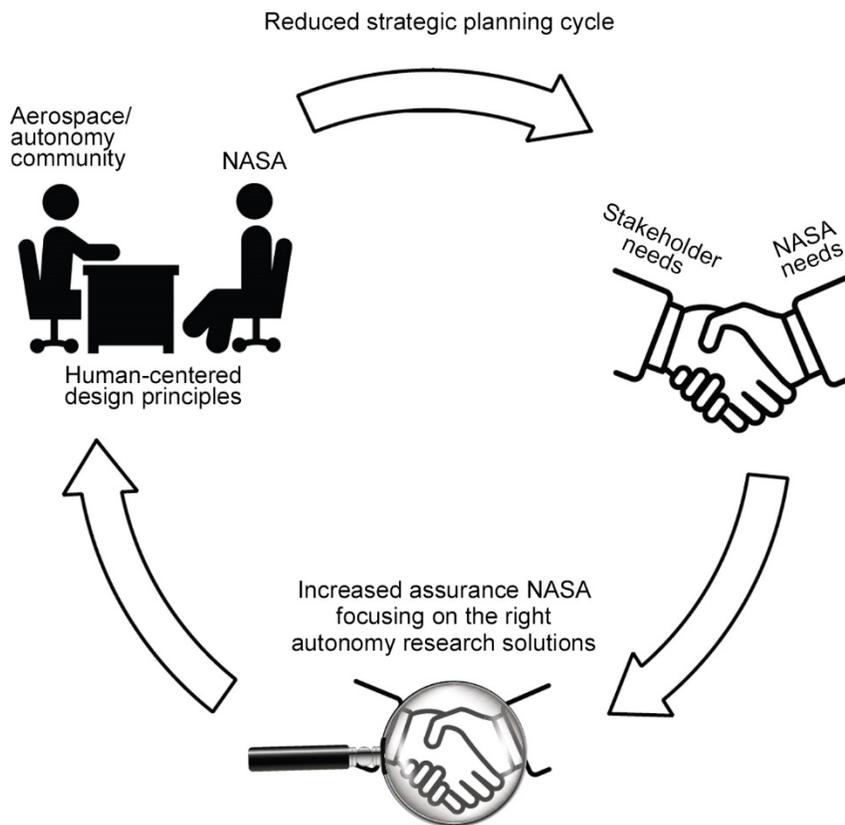


Figure 4.—Never Stop Interviewing concept potential benefits.

## **Opportunity Problem**

The Opportunity Problem concept suggests that organizations, when soliciting request for proposals, should structure work around opportunities instead of single technological ideas. This is based on the premise that one can eliminate an idea from consideration, but one cannot eradicate a valuable opportunity. Instead of NASA supporting an effort exactly as constrained in the proposal budget and work plan, the Agency allows more liberty to vary delivered solutions after contract award. Such changes occur outside of the existing contract modification process.

This allows researchers to quickly transition the work focus, if necessary, to drop designs that are not progressing rather than being contractually obligated to perform a predetermined amount of effort on a topic. It is expected that by aligning communities inside and outside of NASA to wholly confront ambitious challenges, the work focus shifts to better address genuine problems with reduced total research costs and increased pace. Still, this is outside current NASA practices and requires exceptionally careful oversight to ensure the independence is not abused.

## Planetary Flight

The market is quite crowded in regard to developers of small unmanned aerial vehicles (UAVs) and intelligent control system developers. As a result, the AATC group struggled to identify a distinct and advantageous position for NASA in terrestrial small-scale flight. Though AATC was an aeronautics project, there is another major focus within NASA. This is, of course, space research and astronautics. An aerial mission on another planet is of great scientific interest to many individuals within the Agency, but it is not necessarily obvious on the aeronautics side. Aeronautics and Space directorates merging objectives improves the likelihood of realizing Entomopters on Mars or balloons on Titan (Figure 5).

It is possible for NASA to refocus vehicle technology research to support an autonomous science mission. Such a mission provides a rapid and efficient means of data collection for unexplored locations. This places NASA in a unique space in unmanned aerial system (UAS) and autonomy research. Multiple centers are then involved in meaningful technology development that is not in direct competition with established commercial industries.

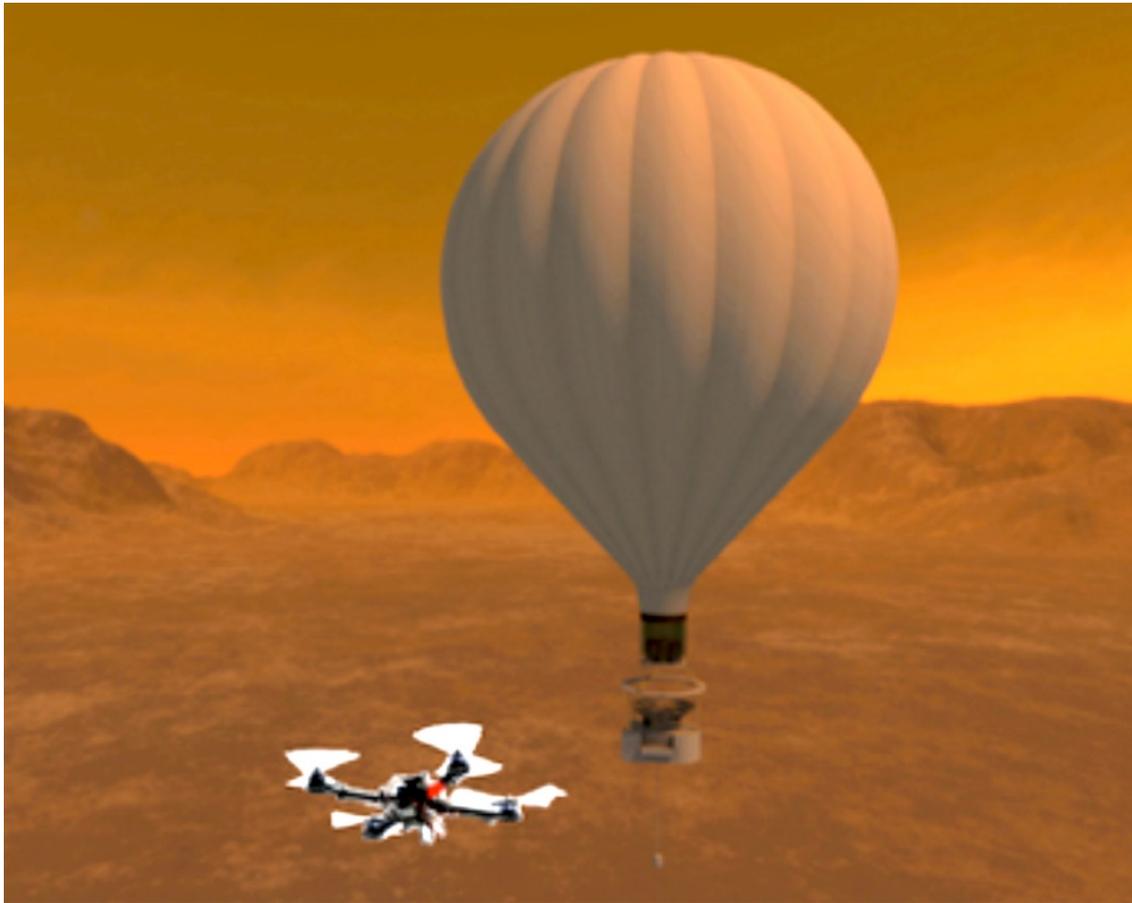


Figure 5.—Exposition of Planetary Flight concept.

## Rank System

The Rank System concept (Figure 6) is a series of autonomy expertise levels assigned to individuals, university research groups, or businesses so that their accomplishments are readily ascertained by others. This idea was initially generated as part of the Simulation to Flight concept so that high-performing teams could be easily recognized for successful competitive flight performances. It could also be a mechanism for managing priority of inputs for the Virtual Aircraft Control Room concept.

A major objective is to create a mechanism to connect and recognize flight research developers from diverse specialties. By instilling a sense of virtue and honor in attaining a new, higher level of recognition, NASA hopes to encourage participation from all researchers. Ranking up potentially results in monetary compensation, status rewards, or facility and consultation access privileges.

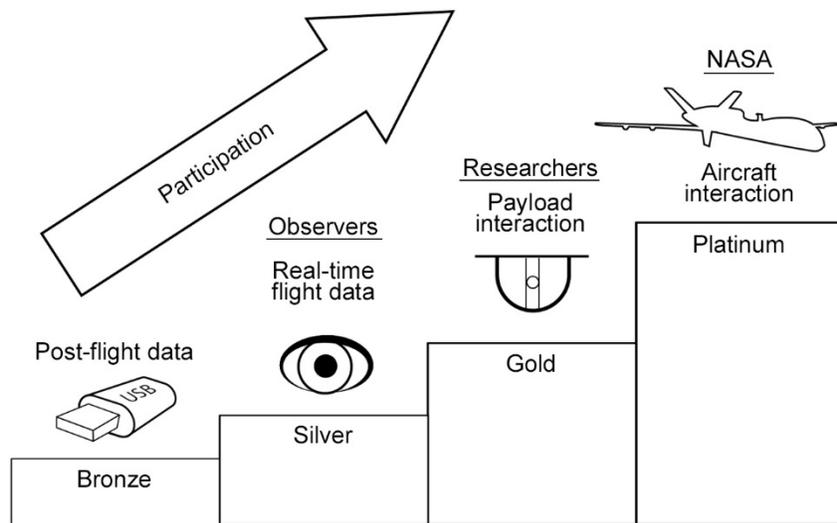


Figure 6.—Rank System concept. USB, Universal Serial Bus.

## Red Lantern

Historically, in the Tour de France cycling stage race, the two most acclaimed riders consist of the overall classification winner and the individual who finishes last. This final finisher is thereafter known as the *lanterne rouge*, French for the red lights typically located at the rear of the rearmost railroad car (Figure 7). It may seem illogical to honor someone who is hours behind the victor, but it must be noted that oftentimes a quarter of the starting racers fail to finish the event. Thus, the award is truly in the spirit of celebrating the challenging experience presented by the 3-week spectacle.

This concept presents a potential award and further research funding for projects that notably missed initial objectives but still managed to significantly contribute to advances in aviation and autonomy development. Even though many successes involve failures and diversions along the way, these failures, no matter how valuable, are often ignored due to the pressure for academics to publish only positive outcomes. To obtain value from learning that occurs by unexpected or even accidental means, it is beneficial to seek to recognize instances in which success varies from the presupposed. This could help create a culture of openness to more freely share results, reduce the fear of failure, and more holistically evaluate outcomes. The concept provides a new way to identify and fund individuals who are more inclined than others to be daring and take appropriate risks. There is a similar current NASA Innovation award known as the Lean Forward; Fail Smart award, and this concept suggests there could be usefulness in tying additional funding to that honor.



Figure 7.—Red Lantern concept symbol.

## Remote Flight Facility

The Remote Flight Facility concept (Figure 8) offers to make available NASA exclusive test resources including facilities and commercial off-the-shelf, multipurpose vehicles to those in industry and academia. Though this is similar to the Fast NAS concept in attempting to improve utilization rates of existing NASA test resources, more responsibility here rests with NASA for new technology integration since the technology developers are not expected to always remain onsite. There is still simplified and ready access without a significant time delay from proposal to actual operation, but extensive NASA support allows for more radical test situations ranging from indoor to net to open outdoor operation. The Agency shares flight operation infrastructure and existing review processes including safety oversight.

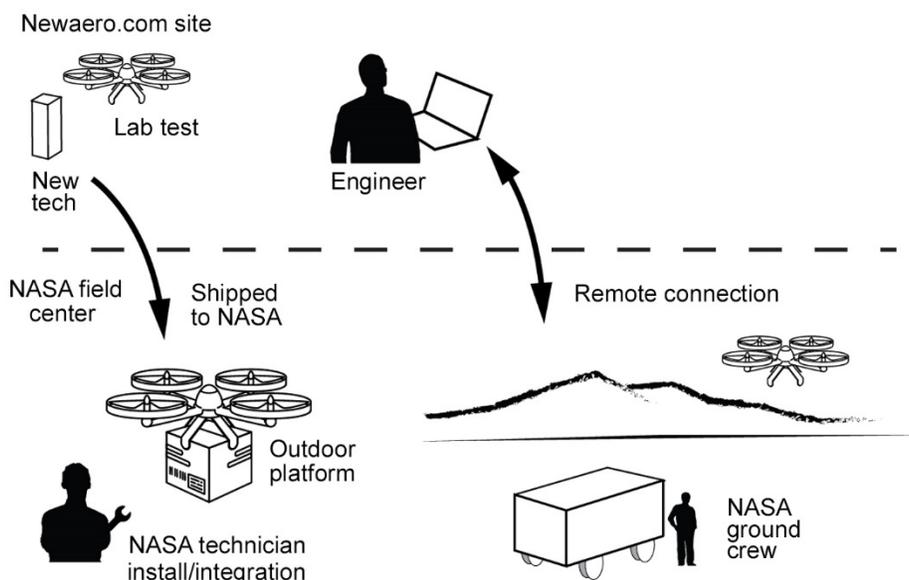


Figure 8.—Remote Flight Facility concept.

## Simulation to Flight

In the Simulation to Flight concept (Figure 9), a detailed autonomy flight mission is generated for NASA aircraft. Simulation environments are provided to remote competitive teams that register to participate in a competition involving these aircraft along with sensors and a flight course map. An example competition is a quadcopter sense and avoid challenge utilizing vision algorithms in urban surroundings to appraise a variety of solutions used by remote teams. Organizations external to NASA form teams and develop systems to fly through the simulated environment. The next stage is to perform the same tasks in a real UAS that NASA assembles prior to navigating through the course. Teams score points by accomplishing goals established in the mission profile.

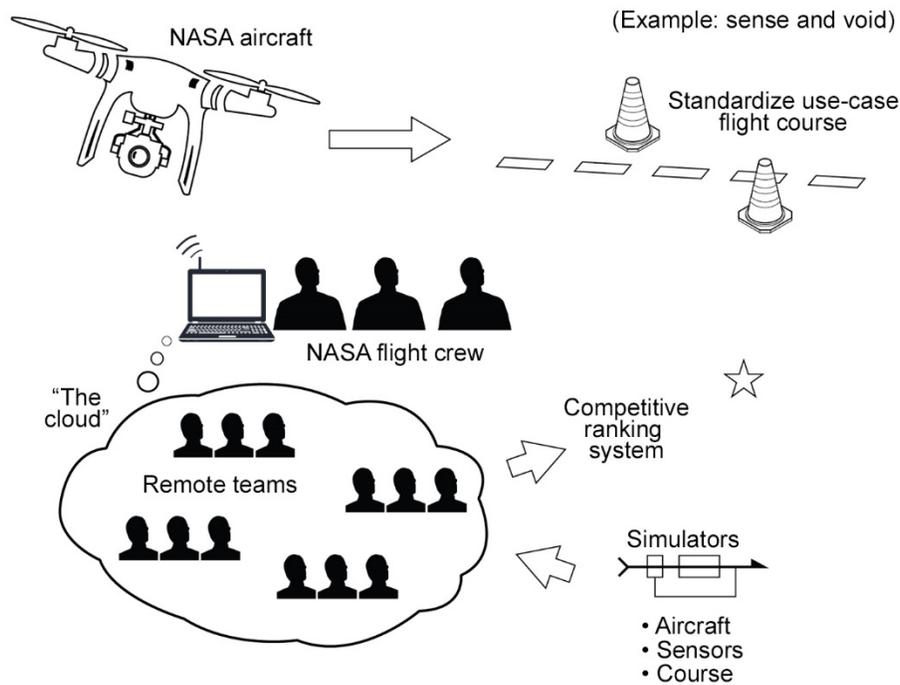


Figure 9.—Simulation to Flight concept.

## Special Operations

Instead of NASA hiring expert consultants, the Special Operations concept (Figure 10) suggests turning the knowledge transfer around by creating interdisciplinary and multicenter teams of civil servants with a focus on autonomy. These teams are then offered to serve the needs of nontraditional aerospace partners through short term co-located projects. With a rapid, short-term, focused, and collaborative setting, NASA enables smaller aerospace partners such as startups to readily contribute toward high-impact and innovative developments from low-TRL aerospace research. Special Operations team member visionary projects provide direction for the immediate strategic goals.

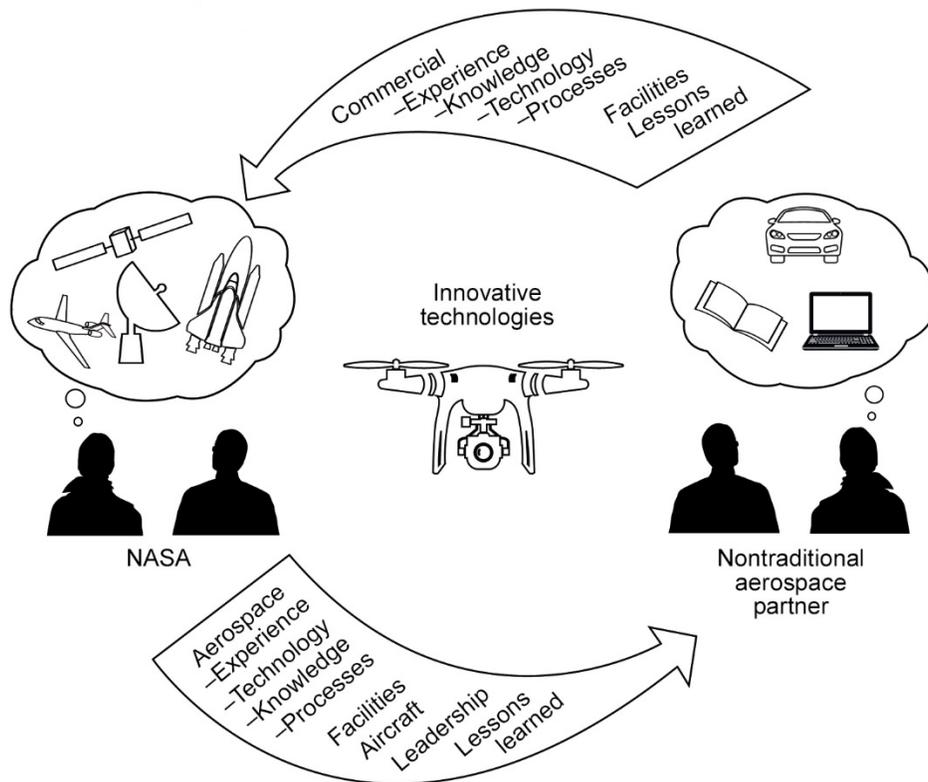


Figure 10.—Expertise sharing in Special Operations concept.

## **Unmanned Aerial Vehicle (UAV) Open**

The UAV Open concept suggests a CrossFit® Open style, NASA-supported, crowd-source regulated competition consisting of alluring, scalable, and technologically challenging events. CrossFit® is a form of fitness programming that hosts an annual three-round competition to determine the most all-around fit man and woman. In the first round completed at local gyms, individuals pay a small fee and perform challenges that are timed, scored, and video-recorded to enable online judging. As the competition advances, the finest entrants are brought together to complete more complex workouts live in an arena with an audience. It is possible to establish a similar event for autonomous flight vehicles or simply UAS operation. In the UAV Open, the events can change over time to reflect technology advances and can be performed entirely independent of one another. An ideal event could be performed by a single individual filming himself or as a co-located group. For example, imagine a maximum flight distance contest recorded by a small action camera as a drone flies over a high school track with the result later posted to a NASA-hosted website.

Primarily, this concept aids in solving collaboration issues. To attack challenges at a high level necessitates SW, energy storage, propulsion, and manufacturing technology developers to form alliances. More novice users can still participate by using UAVs in this positive environment and be exposed to the methods employed by elite operators. There is a potential to bring together the full spectrum of UAV and autonomy users and designers. In regard to the implementation of this concept, the significant difficulties include the enormous organizational burden to guarantee meaningful participation and accommodation of the risk for amateur drone flight. Existing UAV Challenge and Drone Racing League competitions prove that these impediments are not impossible to overcome.

## Virtual Aircraft Control Room

In the Virtual Aircraft Control Room concept (Figure 11), a virtual web-based NASA control room exists to network with payload sensors onboard a NASA optionally manned aerial platform during flight. Flight and payload data webstream live during operations to selected autonomy research community participants. An online-based control connection is established to authorized community members, allowing managed flight inputs from payload avionics. This enables remote researcher interaction with the aircraft payload and NASA flight crew. When presented with this concept, interviewees expressed concern regarding the resultant management of intellectual property, data sharing, and flight mission development.

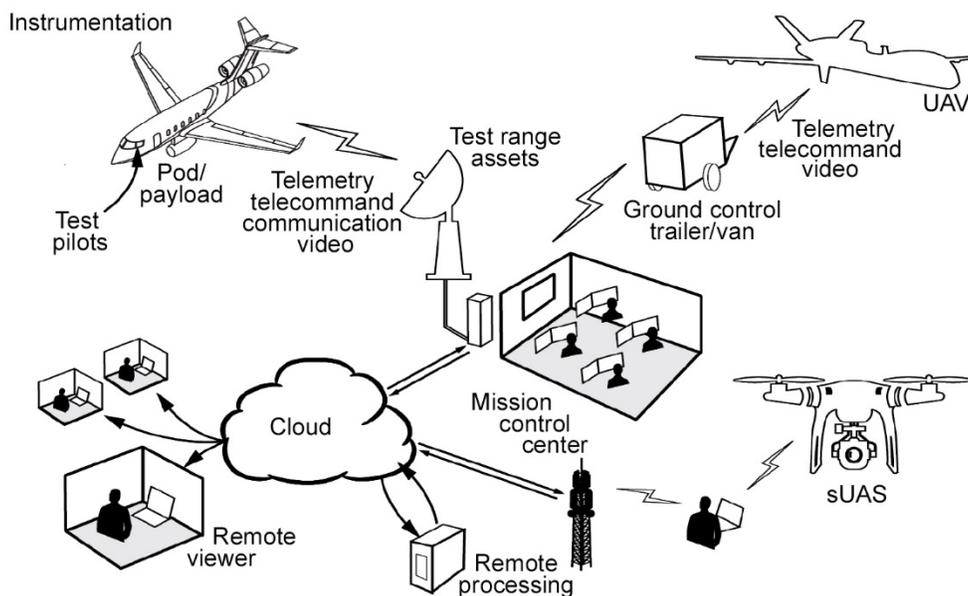


Figure 11.—Virtual Aircraft Control Room concept operations. sUAS, small unmanned aerial system; UAV, unmanned aerial vehicle.

## Virtual Autonomy Toolbox

Reminiscent of the NASA Autonomy Operating System for UAVs project, the Virtual Autonomy Toolbox concept (Figure 12) attempts to develop autonomy test capabilities based on simulation models, toolboxes, and multiuser virtual environments. Developers often desire to assess autonomy technologies and ideas using modeling and simulation without the ultimate objective to proceed to actual flight testing. By connecting the needs of a researcher to new or existing virtual test capabilities, this concept lessens the necessity to occupy flight operations resources for initial testing of concepts. It is possible that this concept could be integrated as a feature into the Simulation to Flight or Second Round Autonomy Portal concept.

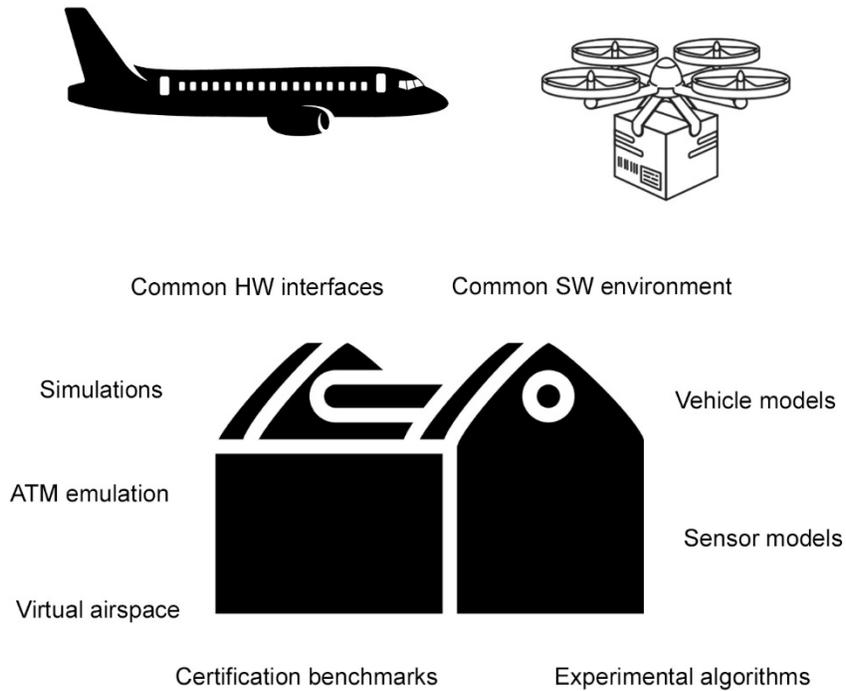


Figure 12.—Core attributes of Virtual Autonomy Toolbox concept. ATM, Air Traffic Management; HW, hardware; SW, software.

## Second Round

### Airportable

The Airportable (Figure 13) concept represents a desire to get UAVs to testing locations that are likely inaccessible to many researchers. This concept was initially named Autonomy Carrier Testbed and depicts an operations base consisting of an unmanned aircraft transporting sUASs to desirable and safe testing environments with high potential for useful data collection. By launching and retrieving smaller vehicles in midair, similar to the goal of the Defense Advanced Research Projects Agency (DARPA) Gremlins program, multiple research aircraft are quickly delivered and flown at the same time.

This is established to reduce barriers to flight, improve multiple-UAV operation safety, improve research agility, and connect autonomy development communities that are not presently working together. The primary implementation issues include current regulatory constraints and uncertainty within NASA regarding the most desirable scale size for such a platform.

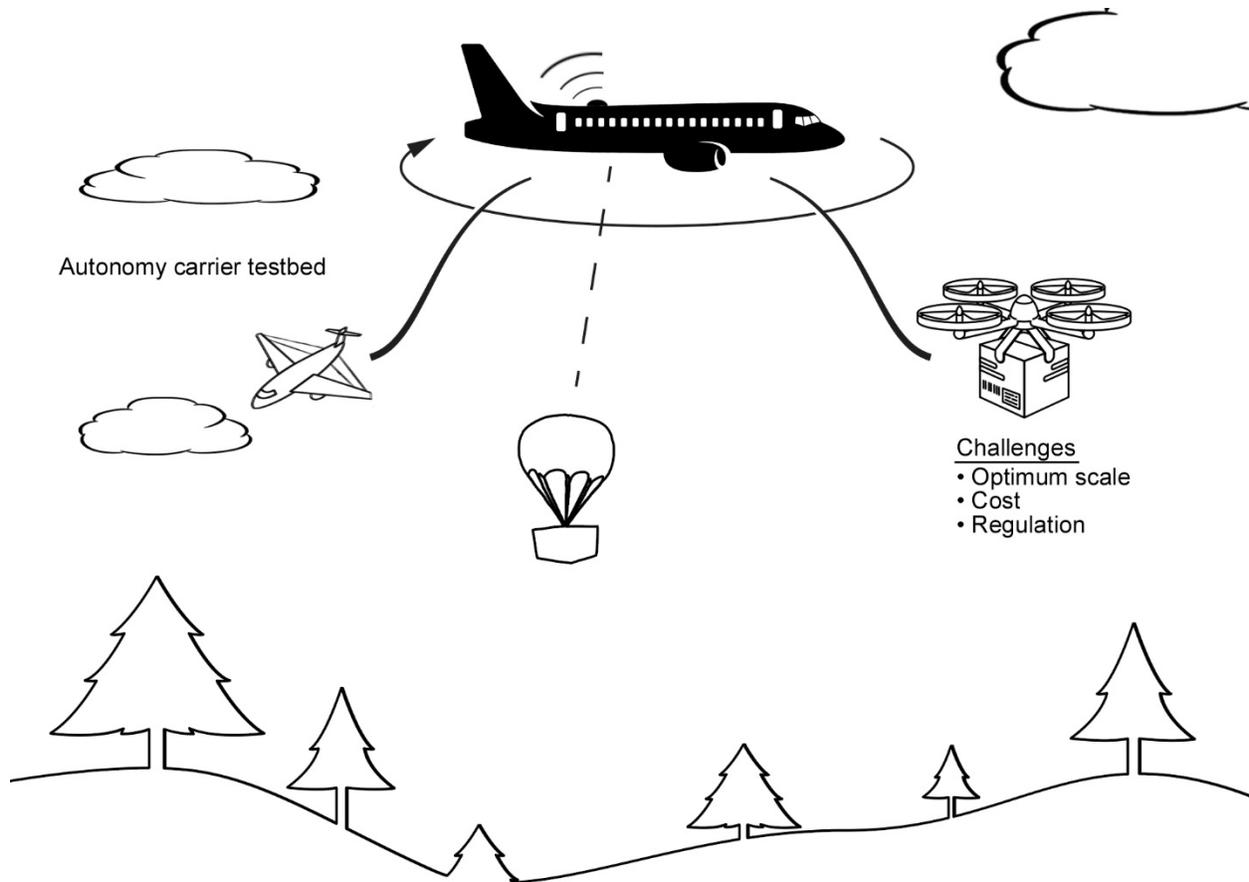
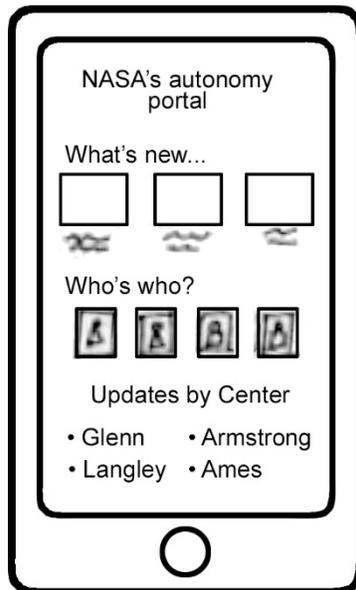


Figure 13.—Airportable concept deployment.

## Autonomy Portal

The Autonomy Portal concept (Figure 14) is an online gateway or application to connect all available autonomous information and knowledge within NASA. This furthers understanding of the greatest current challenges so that managers and researchers plan more effectively when deciding future activities. The portal incorporates some features of and be able to integrate with the existing NASA Hyperwall to promote presentations of the most fascinating and important autonomy work. As a living product, it is necessary to employ a team to manage and edit the program.

If only NASA workers are invited to use the product due to intellectual property concerns, active employee participation is even more crucial to provide rapid and effective value to the greater autonomy community. Ultimately, to reduce barriers to access for outside researchers, connect the community, and improve work agility, there likely must be layers of access within the portal. One potential method for accomplishing this is a social media aspect providing inspirational news and a separate, private section for stimulating discussion around technical presentations.



- Mobile web
- Always accessible
- Constantly updated
- Rotating team

Figure 14.—Representation of app for Autonomy Portal concept.

## Autonomy Transformation Center

Similar to the conception of the Federal Aviation Administration (FAA) UAS test sites, the Autonomy Transformation Center concept (Figure 15) presents a goal to create a site that is a truly compelling location for technology development. While many FAA test sites claim diverse testing opportunities, during the time period of research for this project, most were limited in the opportunities to operate aircraft beyond a minimal preapproved list. This Autonomy Transformation Center is open to researchers both inside and outside of NASA. The project is preferentially begun at a small scale in order to create some successes and promote management support prior to making significant facility investments or operate larger, costly, and more capable aircraft. Initial work also includes development of a suite of tools, procedures, and assistance systems to ensure safe experimentation.

### Drones for Good

The Drones for Good concept is a team including NASA engineers, technicians, and educators who devise and construct autonomous technologies for demonstrations and real-world applications. This is a variation of the American Institute of Graphic Arts Design for Good program. Recognizing that these sorts of proposals and projects often do not entice strong NASA funding support due to the lack of a distinct technological framing, the AATC group attempted to pair this concept with a specific application. There is some public perception that drones are tools for warfare rather than machines with a place in everyday life. The goal is then to identify an UAS end use that is decidedly positive and innovative.

A potential example of this is an on-demand communications network provided by a fleet of UAVs. These provide support for ultra-reliable communications in emergency scenarios such as large fires or other rescue operations. In the autonomy and communications development communities, NASA expertise and relationships are utilized to create complete packages to share or license to other governmental organizations or contractors employing first responders. This emergency assistance product serves to build public trust in autonomy while NASA is able to develop new technology partners, integrate autonomy into worthwhile applications, and provide a fun and rewarding work activity for current employees.

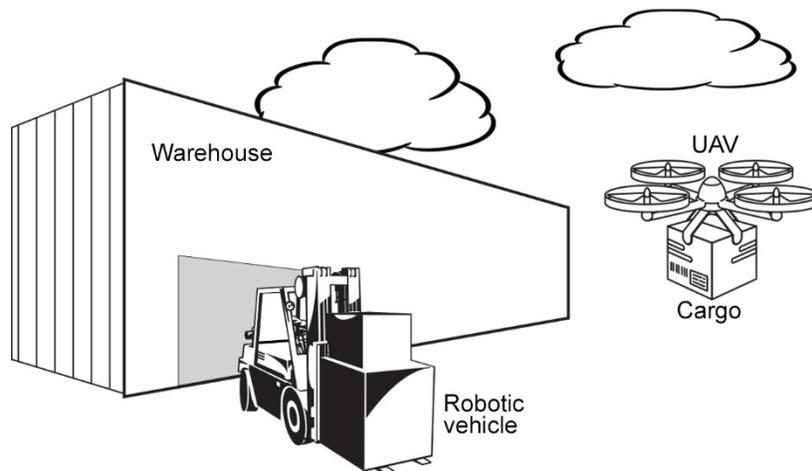


Figure 15.—Autonomy Transformation Center concept. UAV, unmanned aerial vehicle.

## Full-Scale Testbed

There is a significant amount of data that is created on every airplane flight that is either never shared beyond the airline and manufacturer or discarded a short time after the flight. An opportunity exists to significantly expand the availability of such data and provide autonomy researchers with a more modern and expansive history of operations. The Full-Scale Testbed concept applies this data to enable more extensive future simulation and improves the safety of current airliners by using large-scale data mining to identify unknown errors and risks. The challenge here is that existing large-scale aeronautics entities will likely resist release of such data in case of liability when faults are discovered.

## Modular Components or Facilities

A refinement of the Remote Flight Facilities concept, this Modular Components or Facilities concept (Figure 16) retains the desire to share and connect existing NASA competencies. The primary purpose remains to serve small-scale research needs and, later, public outreach viewing requests. Here, NASA provides mobile makerspaces that are continuously updated to match the projected UAS state of the art. The fabrication labs eventually lead to physical construction of new test spaces that are standardized to compare performances from multiple locales.

With modular components, NASA designs a HW platform with interoperability of foremost importance and allotting space for supporting instruments such as sensors. The platform thus becomes highly desirable in comparison to regularly modifying existing systems. NASA must strive to create enthusiasm from industry and academic developers to standardize important interfaces between various subsystems with communications to key partners.

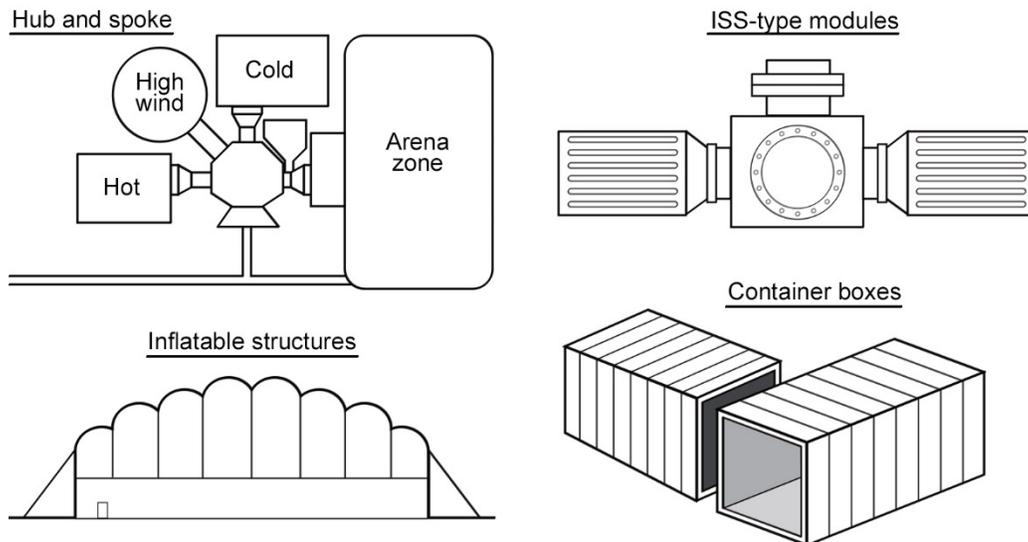


Figure 16.—Potential Modular Components or Facility concept structures. ISS, International Space Station.

## **Conclusions**

In retrospect, it is worthwhile evidence for the efficacy of design thinking to note that a small team, one consisting of mostly nonexperts in autonomy, independently developed so many convincing concepts. The existence of the Unmanned Aerial Vehicle (UAV) Challenge and the Defense Advanced Research Projects Agency (DARPA) Gremlins program proves that many of these ideas are significantly more practical than a critic may initially suppose. There are many potential starting points here for researchers and developers searching for pathways to improve the coordination of the autonomy research community and provide platforms for demonstrating, sharing, and improving relevant technologies. Hopefully more of these concepts, especially those that appear the most far-reaching, will be realized by individuals and teams within NASA, academia, and industry.

## **References**

1. McGowan, Anna-Maria; Bakula, Casey; and Castner, Raymond: Lessons Learned From Applying Design Thinking in a NASA Rapid Design Study in Aeronautics. AIAA 2017-0976, 2017.





