Ascending UNMANNED from the Middle Kingdom

By Robert C. Michelson

China is called Zhōngguó in Mandarin Chinese (中国). It's a name dating back to the Han Dynasty (206 B.C. – A.D. 220). The first character zhōng means "central" or "middle," while guó means "kingdom." Recently, a new name has emerged in the Chinese vernacular: Wú Rén Jī, or UAV (无人机)– unmanned aerial vehicle.

The Chinese UAV industry is off to a fast start with various serious systems under development, one of which rivals the capability of the General Atomics Predator. A tour of the China Aviation Museum outside of Beijing reveals China's aviation history largely began with World War II U.S. warplanes, transitioning to Soviet manufactured aircraft, and then Chinese-made copies of Soviet aircraft, to today's original Chinese military and commercial designs. Whereas things were once "made in China," they are now "made by China."

Now, as has been ongoing in the western world for nearly a quarter of a century through the AUVSI International Aerial Robotics Competition, China has established its own competition focused on unmanned aircraft technology.

This past August in a field adjacent to the China Aviation Museum in the outskirts of Beijing, a mockup of an aircraft carrier deck was constructed as part of the International UAV Innovation Grand Prix. Dubbed the AVIC Cup, this event was co-organized by the Aviation Industry Corporation of China (AVIC) and Chinese Society of Aeronautics and Astronautics in celebration of the 60th anniversary of China's aviation industry.

The AVIC Cup

The AVIC Cup was composed of a Creativity Grand Prix and an Athletics Grand Prix. The Creativity Grand Prix solicited competitors from industry and academia with the most innovative UAV platform solutions. The Athletics Grand Prix drew from the same engineering base, but focused on fully autonomous UAV flight. Specifically, an autonomous UAV was required to take off, circle the airfield over the carrier deck mockup, and then land on while snagging the second arresting cable among four that spanned the deck. The highest award given for the Creativity Grand Prix and Athletics Grand Prix, respectively, were 300,000 Chinese yuan ($47,300) and 500,000 yuan ($78,800). The total award money for all categories of the grand prix was 2,650,000 yuan ($417,800).

A view from the deck of the carrier mockup with the arresting cables.

The organizers had hoped to attract an international slate of teams, but predominantly due to a late start in publicizing the event internationally, only one team from outside China brought an entry. That team was from nearby South Korea. Nonetheless, there were more than 100 entries to the AVIC Cup, coming mostly from Chinese universities.

I was honored to be selected as one of two international judges officiating at the event, the other being from South Korea. In this capacity, we were to arbitrate any questions arising from the myriad of line judges who were monitoring various aspects of each demonstration or flight. The entire event was conducted in Chinese, so I was provided with a personal English translator, Xue (meaning "Snow" in Chinese), who was employed by the Chinese Society of Aeronautics and Astronautics.

The AVIC Cup lasted for several days due to the large number entries. From my perspective, the most interesting part was the Creativity Grand Prix, because that is where future technologies were being demonstrated. The Athletics Grand Prix, while interesting in its own right, was showing levels of autonomous behavior that had been demonstrated by various teams in the International Aerial Robotics Competition nearly a decade earlier. In particular, autonomous takeoff, navigation and precision landing of fixed wing UAVs is established technology.

Athletics Grand Prix

In the Athletics Grand Prix, the entries were mostly instrumented, large-scale (two- to four-meter wingspan and eight- to 20-kilogram gross takeoff weight), fixed-wing planes of a planform similar to most high-wing tractor-prop model aircraft. There were a few successful twin-tail boom pusher-prop entries as well. One the most stable and impressive flight demonstrators, which consistently performed the autonomous carrier deck landings, was a vehicle closely resembling the X-45A unmanned combat air vehicle with the addition of twin Predator-like vertical stabilizers. This ducted fan developed by the Shenyang Aircraft Design and Research Institute and Shenyang Aerospace University made multiple successful, highly stable flights,

culminating in carrier deck landings until its final flight on the last day of the AVIC Cup, when it sustained a catastrophic equipment failure moments after takeoff, which resulted in the destruction of the vehicle.

Creativity Grand Prix

During the Creativity Grand Prix portion of the AVIC Cup, teams demonstrated both subsystems and complete air vehicle concepts. Key to the Creativity Grand Prix was the demonstration in hardware of innovative flight principles and radical aerodynamic layouts. By and large, the entries in the Creativity Grand Prix were not autonomous.

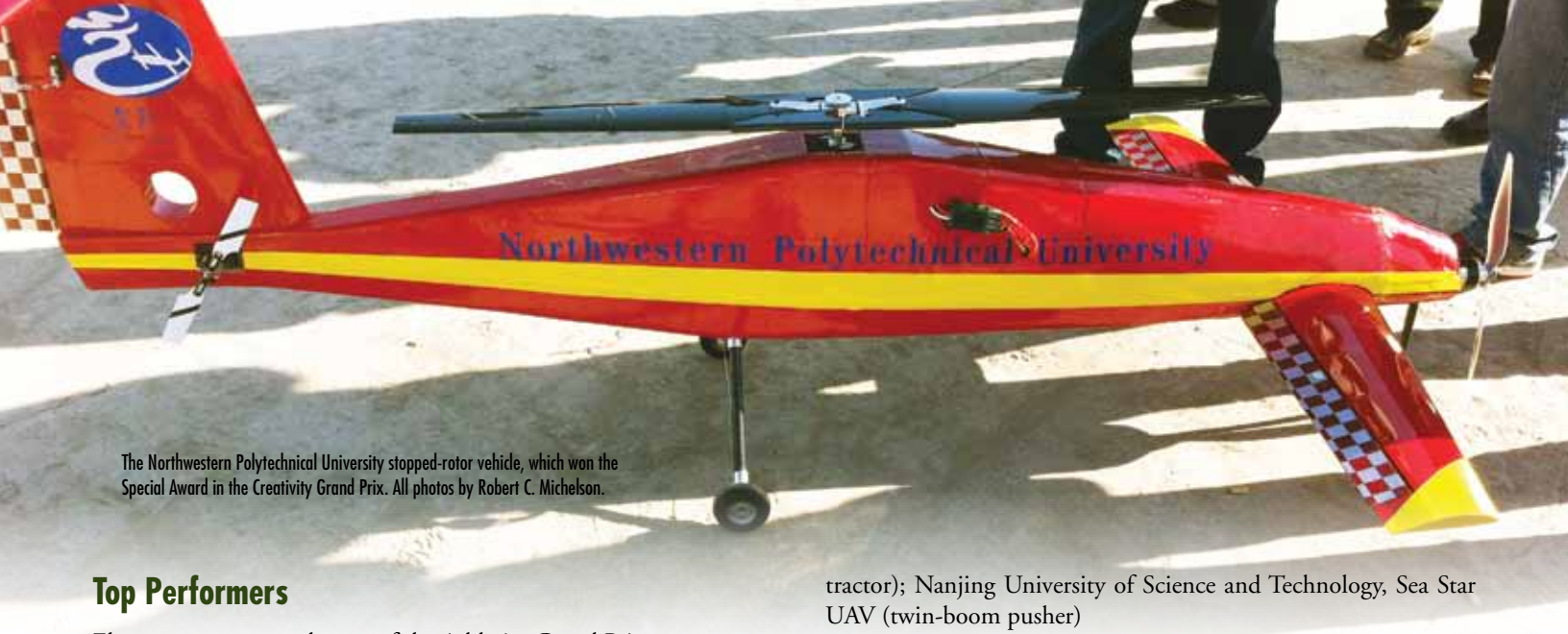
Scoring of the Creativity Grand Prix was based on an innovation score, an availability score and a reality score. Emphasis was on the innovation score, which focused on:

1. Unique principles (including but not limited to principles of flight, propulsion and control)
2. Innovative layout (including but not limited to aerodynamic, structural and functional layout)
3. Mode innovation (including but not limited to flight mode, takeoff and landing methods, and applications)
4. Integration of elements (including but not limited to cultural, environmental and cost elements).

The availability ccore involved a comprehensive evaluation based upon the task capabilities and features of the UAV, such as overload capability, high mobility, and long endurance.

This shows the UCAV-like UAV from the Aviation Industry Corp. of China.

The reality score considered the actual physical production of the UAV (it couldn't simply be a concept), the ability to takeoff under its own power, flight control stability and the ability to land without damage.



The Northwestern Polytechnical University stopped-rotor vehicle, which won the Special Award in the Creativity Grand Prix. All photos by Robert C. Michelson.

Top Performers

Eleven teams rose to the top of the Athletics Grand Prix.

* **Special Award:** Nanjing Tianyi UAV Co. Ltd., Flying Fox (twin-boom pusher)

* **First Prize:** Nanchang Hangkong University, Changsheng General Utility UAV (high-wing tractor); Northwestern Polytechnical University and University of National Defense, Hercules UAV (high-wing tractor)

* **Second Prize:** Beijing Institute of Technology and Institute of Atmospheric Physics, Chinese Academy of Science, Expedition No. 5 (twin-boom pusher); Beihang University, P3000 (high-wing tractor); Nanjing University of Science and Technology, Sea Star UAV (twin-boom pusher)

* **Third Prize:** Beihang University, X Aviators (high-wing tractor); AVIC Shenyang Aircraft Design and Research Institute and Shenyang Aerospace University, Tiannu (ducted fan in the style of an unmanned combat air vehicle); Xiamen University, Nanqiang UAV (high-wing tractor); Shanghai Jiaotong University, YY03 UAV (high-wing tractor); Nanjing University of Aeronatics and Astronautics, Osprey carrier-borne aircraft (high-wing tractor).

Sixteen teams won prizes in the Creativity Grand Prix portion of the AVIC Cup.

* **Special Award:** Northwestern Polytechnical University, Smart Loong UAV (stopped-rotor UAV)

* **Honorable Mention:** Northwestern Polytechnical University, Homing Pigeon reconnaissance system (flapping-wing "bird"); AVIC Shenyang Aircraft Design and Research Institute and Shenyang Aerospace University, UAV with four control surfaces (ducted fan in the style of an unmanned combat air vehicle)

* **Star for Future Award:** Nanjing University of Aeronautics and Astronautics, Golden Eagle differential flapping flight vehicle (flapping-wing "bird")

* **Star for Mission Award:** AVIC Chengdu Aircraft Design Institute, vertical takeoff and landing morphing aircraft (similar to the Boeing Heliwing)

* **Star for Hope Award:** China Aviation Museum, manual-control Eagle (fixed-wing tractor prop)

* **Excellence Awards:** Northwestern Polytechnical University, Hot Wheels rolling-wing aircraft (fan-wing platform); Nanjing University of Aeronautics and Astronautics, X flying vehicle (fan-in-wing cruciform vehicle with control vanes); AVIC Chengdu Aircraft Design InstituteBerserk UAV (ducted-fan lifting body); Beijing Institute of Technology, Golden Swing UAV (vertical takeoff and landing ducted fan with multiple forward and down-blowing fans); Beijing Institute of Technology, Falcon UAV (joined wing); Xi'an Aircraft Industry (Group) Co. Ltd., SA-100 UAV (high wing with canard); Beiyang Star Lab, Co-axial unmanned helicopter (co-axial helicopter with pusher prop); Nanchang Hangkong University, City Elf fixed-duct UAV (counter-rotating fixed-pitch ducted fan

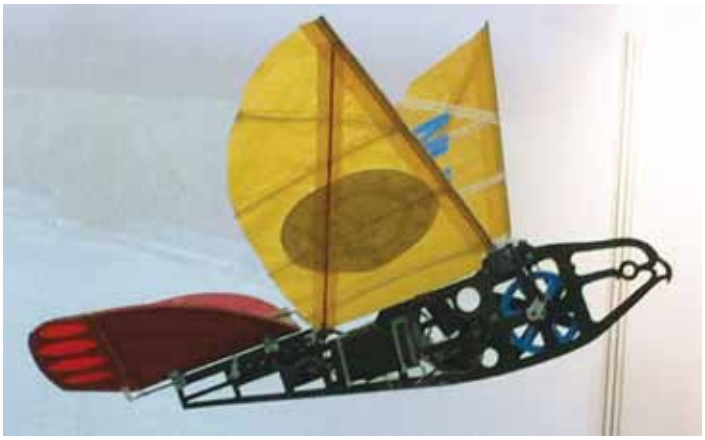
with outrigger stability fans); Nanjing University of Aeronautics and Astronautics, Phantom no-control-surface UAV (articulated opposite-twist wings for aileron control); Nanjing University of Aeronautics and Astronautics, Dream Morpher UAV (variable geometry wing tips).

Significant Technologies

Of the winning innovations, the top technologies that I found most significant were the Northwestern Polytechnical University stopped-rotor vehicle and the Nanjing University of Aeronautics and Astronautics differential flapping-wing vehicle.

The quest for a vertical takeoff and landing vehicle that can transition into high-speed forward flight has been sought for years. During the 1980s, DARPA and NASA funded the Sikorsky X-Wing project, which involved a rigid helicopter rotor that could be stopped in flight to act as a wing. After significant expenditure, and never having demonstrated conversion from hover to forward flight and back, the X-wing project was canceled. The V-22 Osprey tiltrotor was able to fill the X-Wing flight envelope, albeit with more complexity. Around 2003, under joint development by Boeing Phantom Works and DARPA, Boeing attempted to demonstrate stopped-rotor technology with its canard rotor/wing X-50A Dragonfly UAV. After several years of testing, Boeing had crashed both of its demonstrators without being able to transition to and back from forward flight.

During the AVIC Cup, the Northwestern Polytechnical University stopped-rotor UAV performed flawlessly, transitioning from hover to high-speed forward flight and back again on several occasions. This stopped-rotor design employed a single main rotor that could become symmetrical and lock in a rigid position that was orthogonal to the fuselage. Because a single rotor was used, the vehicle had a tail rotor. In addition, there was a tractor prop at the nose of the fuselage. All propulsion systems were electric in the UAV version, but a larger vehicle was shown in animation operating from a helipad and a carrier deck. In light of the millions of dollars spent by DARPA to develop a workable stopped-rotor design without ever demonstrating conversion, I found the fully functional Northwestern Polytechnical University stopped-rotor UAV to be one of the most significant technology demonstrators at the AVIC Cup.



The Nanjing University of Aeronautics and Astronautics electric bird UAV, which is autonomous and navigates by GPS.

Second on my list of significant technologies was the Nanjing University of Aeronautics and Astronautics flapping-wing UAV. The reason that this vehicle caught my attention was that it varied its flapping-

wing geometry to effect differential lift in order to control stability and to navigate. Most flapping-wing vehicles are a synthesis of wing flapping for propulsion with conventional rudders/elevators for control as seen in the DeLaurier and Festo AG ornithopter designs as well as Japanese "bird toys." The Nanjing vehicle's non-resonant, electrically driven wings and fixed tail for trim allowed autonomous GPS-guided flight for up to 20 minuits from a lithium-polymer battery. The vehicle size is on the order of a pigeon's body and wingspan.

Many other unusual vehicles were demonstrated, such as the Northwestern Polytechnical University cycloidal rotor vehicle, a fan-wing vehicle, and various tilt-wing, compound helicopters and ground-effect vehicles. While innovative in many ways, a lot of these vehicle concepts have been demonstrated in similar forms elsewhere over the years.

All in all, the AVIC Cup was a tremendous success in that it met its goal of fostering demonstrated innovation. This is not unlike the goal of the AUVSI International Aerial Robotics Competition, which has for the past 21 years been able to advance the state of the art in aerial robotics through demonstration. The similarities in goals between the AVIC Cup and the AUVSI IARC has not gone unnoticed by China's unmanned aircraft industry, so in a spirit of cooperation, a parallel AUVSI International Aerial Robotics Competition venue has been established.

New IARC Venue

Because of the expense of travel, teams from Asia and Australia can be at an economic disadvantage when entering the International Aerial Robotics Competition. The organizers have now created two parallel venues, one in Grand Forks, N.D., and one in Beijing. Teams can compete in the IARC's Mission Six at one or the other venue under the same rules. All procedures will apply equally at either venue.

With two venues operating nearly simultaneously on opposite sides of the planet, competition arenas, judging, rules and procedures will be uniform across both venues. Asia judges and America judges will confer via Skype and in person, while representatives from both venues will be present at the each venue. A winner for Mission Six could emerge from either venue, and were there to be nearly equivalent winning performances from both the America and Asia venues, a "fly-off" between the top two contenders would be considered at one of the two venues with a level of travel support for the team traveling the longest distance.

New applications for International Aerial Robotics Competition events beginning in 2012 will be made available through the official IARC website, http://iarc.angel-strike.com; however, the online application form now provides a space for designating the venue of choice.

Robert C. Michelson is a past president of the Association for Unmanned Vehicle Systems International, recipient of the AUVSI Pioneer Award and the originator of the AUVSI International Aerial Robotics Competition. As a member of the research faculty at the Georgia Tech Research Institute, he holds the title of principal research engineer emeritus.

The fan wing, or rolling wing, vehicle from Northwestern Polytechnical University. It is named Hot Wheels.