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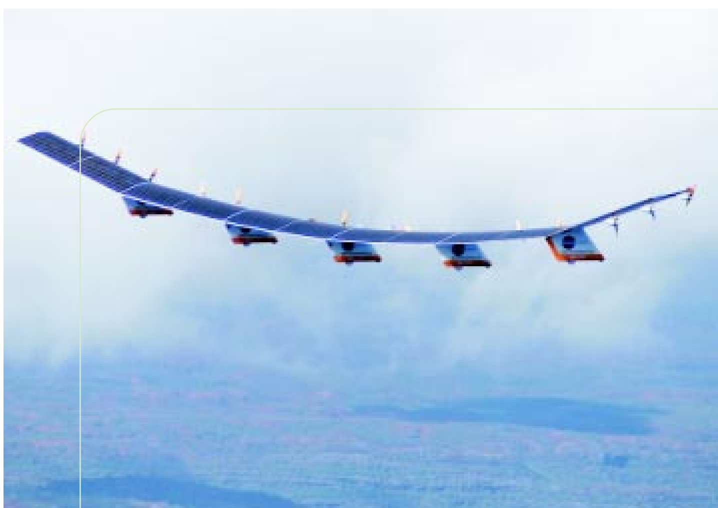
NATIONAL CONSORTIUM ON REMOTE SENSING IN TRANSPORTATION
INFRASTRUCTURE

UAV 2003

A Road Map for Deploying Unmanned Aerial Vehicles (UAVs) in Transportation



A SPECIALIST WORKSHOP

U.S. DEPARTMENT OF TRANSPORTATION
Research and Special Programs Administration

U.S. Department of Transportation
Research and Special Programs Administration

UAV2003
A ROADMAP FOR DEPLOYING UNMANNED AERIAL VEHICLES (UAVs) IN TRANSPORTATION

Specialist Workshop

December 2, 2003
Santa Barbara, CA

Volpe Center
and
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SUMMARY OF FINDINGS

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Foreword

The Research and Special Programs Administration (RSPA) of the U.S. Department of Transportation (USDOT) sponsors a program of research in remote sensing and spatial information systems in transportation, described at *www.ncgia.ucsb.edu/ncrst/synthesis*

The program was the first attempt of such magnitude to explore remote sensing applications in transportation. This begged the question: why had transportation applications hitherto been slow to develop? One of the impediments to remote sensing, particularly in the dynamic subject area of transportation, is the uncertainty and latency between an event and the delivery of data to the desktop. The transitory nature of satellite orbits makes it difficult to obtain the right imagery to address continuous problems such as traffic tracking.

A need therefore emerged for sensor platforms that could be focused on a subject of interest, and could be launched quickly. This took on particular urgency in the post-2001 security environment, when transportation departments suddenly felt the need for instantaneous, accurate information on both accessible and remote areas, that could be provided either by massive investment in fixed, wired camera infrastructure, or by agile and responsive mobile sensing platforms.

The NCRST program has pursued a number of initiatives on UAVs, focusing on usability of UAV data for applications, as well as the engineering aspects of flight control and payload miniaturization. Bridgewater State College, Geodata Systems, and the MLB Company developed small winged craft with live video feeds and high resolution still imagery, and examined the suitability of the data for various applications. Iowa State University investigated camera-equipped helium balloons that could be launched at short notice from pickup trucks. The initial successes on all these projects suggested that the next step should be test deployments with state agencies, but safety and regulatory barriers were an issue.

The purpose of the UAV2003 workshop was therefore to exchange notes with other agencies interested in UAVs, and to forge a plan of action to overcome the technical, institutional and other barriers. This should accelerate the deployment of UAVs in state DOTs and other agencies, and realize the benefits of anywhere, anytime remote sensing.

1. Background and Rationale

The goals and structure of the DOT/NASA Program on Transportation Applications of Remote Sensing (RS) and Spatial Information Technologies are discussed at *scitech.dot.gov/research/remote/index.html*. Posted RS program accomplishments and recent symposia described at *www.ncgia.ucsb.edu/ncrst/synthesis* highlight several successful technology demonstrations of micro- and mini-UAVs (MAV) in monitoring and managing traffic flow, detecting pipeline leaks, and collecting imagery for environmental, safety, security, and emergency management applications.

At the October 2003 Joint Program Oversight Committee (JPOC) meeting on RS program review and planning, there was a great deal of interest expressed by the NCRST Consortia to expand UAV demonstration activities during the next 6 year cycle of expected funding under the Surface Transportation Reauthorization legislation (SAFETEA). Consortia plans presented there included UAV research, demonstration, test and evaluation (RDT&E) for a broader range of applications to traffic flow, infrastructure integrity assessment, and safety and real-time hazard assessment and management.

It became evident during the JPOC group discussion, however, that a number of barriers to UAVs deployment exist, which could hamper both the planned demonstrations and prevent rapid technology transfer into transportation practice. The group agreed that there is a pressing need to define the next RDT&E steps and to facilitate the near-term deployment of the lower cost, lower weight, lower altitudes, and safer MAVs for a broader range of potential transportation applications.

At the request of the DOT/NASA Remote Sensing (RS) program manager, Dr. K Thirumalai, and of the DOT and NASA Joint Program Oversight Committee (JPOC), the National Consortium on Remote Sensing in Transportation-Infrastructure (NCRST-I) and the RSPA Volpe National Transportation Systems Center (Volpe Center) co-organized a one day workshop focusing on identifying barriers to near-term UAV deployment for diverse transportation safety and security applications.

The eventual goal is to develop a simple set of guidelines, or Standard Operating Practices (SOP) for UAV deployment by states and local transportation agencies, or by other transportation system owners or operators. The key objective of the UAV2003 workshop was to develop awareness of the principal barriers to deployment, as well as consensus on optimal strategies to overcome these technical, institutional, regulatory and economic barriers.

The workshop background, agenda, list of participants and speakers' presentations are posted at *www.ncgia.ucsb.edu/ncrst/meetings/uav2003*.

The workshop participants (see Appendix A) represented the diverse stakeholders in deploying UAVs for a variety of transportation safety, security and traffic applications, including: federal agencies with existing or emerging UAV programs (NASA, DOT, DHS/TSA), state departments of transportation (Caltrans), nonprofits FFRDC (Aerospace Corporation), university researchers, UAV manufacturers, and technical consulting service providers.

This brief overview of the proceedings complements the posted presentations by summarizing key findings concerning the principal barriers to near-term UAV deployment, and by listing group recommendations on overcoming them.

2. Overview of UAVs and sensors payloads

UAVs have been developed and used since the 1950s with a strong focus on military applications. In recent years the technology has found increasingly diverse civilian federal and commercial applications. A summary of the UAV capabilities presented and discussed at the workshop is shown in Table 1.

Table 1. Capabilities and characteristics of UAV systems presented and discussed during the UAV 2003 workshop (Information taken from the presentations and from online sources: *www.fas.org/irp/program/collect/uav.htm*, *uav.wff.nasa.gov*, *geo.arc.nasa.gov/uav-nra/capabilities.html*)

Vehicle	Endurance (hours)	Payload Weight (kg)	Altitude Capability (feet)
Aerosonde	40	1	20,000
Altus2	24	150	65,000
AV Black Widow	.5	0.0	1,000
AV Dragoneye	1	0.5	3,000
AV Pointer	1.5	0.9	3,000
AV Puma	4	0.9	3,000
AV Raven	1.25	0.2	3,000
BQM-34	1.25	214	60,000
Chiron	8	318	19,000
Darkstar	8	455	45,000
Exdrone	2.5	11	10,000
Global Hawk	42	891	65,000
Gnat 750	48	64	25,000
Helios	17+		97,000
MLB Bat	6	1.8	9,000
MLB Volcano	10	9	9,000
Pathfinder	16	40	70,000
Pioneer	5.5	34	12,000
Predator	29	318	40,000+
Shadow 200	4	23	15,000
Shadow 600	14	45	17,000

The capabilities of the platforms vary based on their design for specific applications, and this is reflected in the variations apparent in Table 1 and Figure 1. The smallest vehicles are *Micro UAV*'s (MAVs) like the *AV Black Widow* developed for military surveillance, law enforcement, and civilian rescue efforts. Their weight and payload are just a few grams with vehicle size in the order of few centimeters. Larger than MAVs are *Small UAVs* (SUAVs) like the *MLB Bat* or the *AV Pointer*. They are designed for local and small regional scales. Their size ranges from tenths of decimeter to a few meters, with platform weights in the order of a few kilograms. SUAVs are reliable and quiet. They usually require only a small operating crew and are launched by hand or from a mobile launch station and don't require an airfield or airport; therefore, they are quite portable, flexible and autonomous in their applications. SUAVs can carry smaller payloads and sensors for continuous traffic monitoring tasks, remote inspections of borders, pipelines and other infrastructure, and for disaster response and recovery. However, higly miniaturized sensors in an integrated compact payload may pose technical constraints. The operation range of most SUAVs is short enough so they can be operated outside of regulated air traffic.

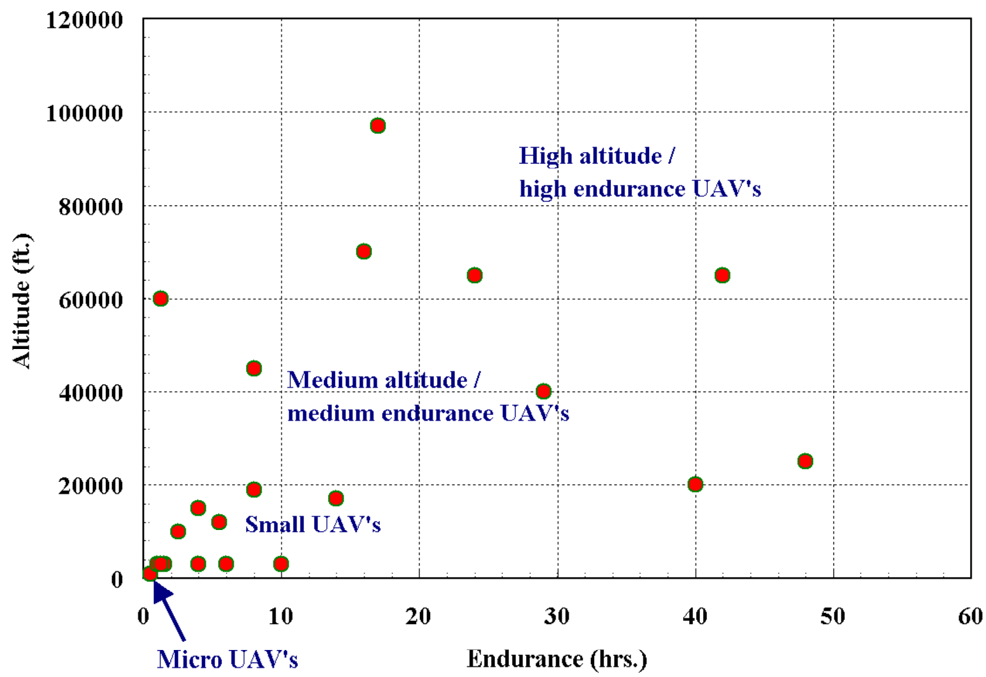


Figure 1. Endurance versus altitude of the UAV systems described in Table 1

Medium altitude and medium endurance UAVs (MUAVs) are mainly used for regional scale observations. Examples have shown their capabilities, e.g. using NASA's *Altus 2* platform for mapping and monitoring of fire hazards, weather phenomena, and for precision agriculture. UAVs that operate in *High Altitude with Long Endurance* (HALE) range, like the *Helios*, are designed to take on and/or complement the operations of satellite platforms. They can work at stratospheric altitudes up to 100,000 feet, with long endurances of weeks to months. They are mainly solar powered and have affordable, persistent and autonomous capabilities for communication, mapping, and monitoring tasks of the earth surface and the atmosphere. Other than satellites, the MUAV system and the payload are recoverable and maintainable, and can be easily upgraded and relocated for continued operation. Both the MUAVs and the HALE UAVs require an airfield or airport for operation and have to be considered as regulated air traffic. The technology of some SUAVs and MUAVs is close to reaching operational status; MAVs and HALE UAVs, with the exception of those tested by DOD and NASA/ERAST, are still in the earlier but emerging stages of development.

Costs of UAVs reflect the type and mission application profile of the systems. Operational SUAVs range in cost from $5,000 to $100,000 including air vehicles, ground station, and standard payloads. HALE UAVs currently require investments in the order of $10 to 100 million. Common payloads carried by UAVs (besides the instrumentation for flight and flight control) are different types of cameras and other remote sensors (real-time video, pointing devices, visible/NIR optical cameras, thermal and hyperspectral mappers, synthetic aperture radar, etc), communication equipment, air sampling instruments and chemical sensors.

3. Barriers to UAV Deployment and Strategies to Overcome Them

In her opening Charge to Participants, Dr. Aviva Brecher, DOT/RSPA Volpe Center, stressed that UAV deployment planning in transportation must be needs-driven. The barriers she identified in her presentation fall in the general categories discussed below, but several may be interrelated and apply simultaneously. The presentations by Dr. Steve Wegener of NASA Ames on "UAV Lessons Learned" and by David Grilley on "Civil/Commercial UAV Operations in the National Air Space (NAS)" discussed both current barriers to UAV deployment, and successful ways to overcome them, further illustrated by the NASA "lessons learned" overview from its UAV research and applications development program.

3.1. Regulatory

The main regulatory barrier identified is the need for developing explicit, yet simple FAA 14CFR safety certification requirements for Remotely Operated Aircraft (ROA) by aircraft configuration and airspace classes. The current FAA Airworthiness certification process by type of aircraft and certification of subsystems and aircraft is very long and complex, as described at *faa.gov/avr/avr.air/air200/200home.htm*

The FAA's mission is to ensure both the "airworthiness" and "equivalent safety" of UAVs, and the safe integration of UAVs into the complex national airspace (NAS) operations. The Certificate of Authority (COA) process is considered too cumbersome and long, with distributed responsibility amongst several FAA regional offices. This means that the FAA must develop in the near-term a more streamlined safety certification process for the UAV vehicle (corresponding to aircraft airworthiness), operators (analogous to pilots) and for National Air Space (NAS) integration (air traffic control rules of the road). The FAA requires that UAVs must have "detect, see and avoid" (DSA) capability onboard to prevent in-air collisions. This is also a technology constraint per 3.8 below. Similarly, a fail-safe option for the mission must automatically apply if the ground to UAV communications link is lost, to prevent hazards from a UAV crashing to the ground (also a technology challenge). Furthermore, the air traffic controllers must both approve the UAV "flight plan" and be aware of UAV proximity to commercial or private aircraft. Again, this might require standard transponders on board, also a technology issue under 3.8, but an economics issue under 3.6 as well.

The FAA already has an MOU with DOD regarding military UAV operations in CONUS air space. The FAA has "certified" about 20 HALE UAVs to date under FAA Certificate or Waiver of Authorization (issued on May 1, 2001 by the Western Pacific Air Traffic Division). However, some military and civilian agency UAV missions to date were required to operate with a costly manned escort in unrestricted airspace, or were allowed only in restricted military airspace, or above unpopulated areas. Using mini and micro-UAVs — because they fall in the unregulated category radio-controlled "model aircraft" (UUAVs) — is not an option. This UUAV unrestricted operation category only applies to amateur aircraft for personal use, but would not apply to "commercial operations.

Clearly, current FAA requirements for UAVs owners and operators to provide proof of "equivalent safety" to manned flight, and delays in reaching the industry goal to rapidly obtain "file and fly" authorization for commercial, state and local UAV missions must be better tailored to the size, altitude (class airspace) and safety of the specific UAV type and its mission. Applicable existing FAA guidelines (Order 7610.4, Special Military Operations and the 1981 Advisory Circular 91-57) must be accordingly updated, as discussed in D. Grilley's presentation.

Multi-stakeholder (agencies, industry, universities) efforts to develop alternative regulatory tools for, and in partnership with, the FAA include:

- The DOD has developed and updated in Dec. 2002 its 25 years strategic UAV technology deployment roadmap *www.acq.osd.mil/usd/uav_roadmap.pdf* , which could be adapted to and benefit manufacturers of civilian and commercial UAVs. For instance, data on failure frequency, and on reliability and maintainability (RAM), as well as on lifecycle cost for the low end UAVs are of special interest to transportation users.
- ACCESS 5 — See briefings posted at *www.uavnas.aero/index.html*. The ACCESS 5 regulatory UAV road-mapping efforts now underway, are funded by NASA, DOD and industry (UNITE) with FAA participation. The effort focuses on the high end UAVs: high altitude, long-endurance (HALE). The phased process proposed would take six years and would apply only to these more costly and technically complex UAVs used primarily by DOD, some of which are now being tested for homeland security applications by DHS and TSA.
- AUVSI — See briefings presented to FAA by this UV industry and trade association on Unmanned Systems status and industry needs posted at *www.auvsi.org/iraq/index.cfm*
- The NASA ERAST program funded the Technical Analysis and Applications Center (TAAC) at the Physical Sciences Lab (PSL) of the New Mexico State University (NMSU) has developed a useful "HALE UAV Certification and Regulatory Roadmap" posted at *www.psl.nmsu.edu/uav/roadmap/Content.htm*
- Several voluntary standards and professional associations (ASTM, RTCA, AIAA, ICAO) have formed UAV standards committees to develop appropriate UAV safe operability standards for the FAA.

An interim option for UAV researchers engaged in demonstration, test and evaluations of UAVs is to obtain an "Experimental Aircraft Certificate (FAA Form 8130-7) or Special Airworthiness Certificate. An even better option, as discussed in NASA presentations, would be to team up with a federal agency and prove to the FAA that there is a public good to be derived from the UAV mission. Most transportation –related activities proposed under the NCRST program would qualify. A valuable and positive NASA "lessons learned" finding was that "FAA is familiar with UAvs and in most regions is amenable to working with UAV teams to obtain a Certificate of Authorization (COA)." with Early FAA involvement in planning UAV missions, as well as frequent communication with the FAA were advised as "best practice" to ensure UAV mission success.

3.2. Security concerns

Security concerns derive from the fact that UAV platforms may serve both research and public good purposes, as well as terrorism or sabotage destructive ends. Remotely operated, radio controlled vehicles, especially if small and unobtrusive, can carry out nefarious surveillance missions, or even transport and deliver explosives, or biological-chemical- radiological-nuclear (BCRN) materials to vulnerable high value, critical infrastructure, or civilian population targets. This means that there must be advance notification of and clearance for a UAV mission to law enforcement agencies and proper authorities. Alternatively, a "squawker" or radio-frequency (RF) transponder could be installed onboard to transmit a signal at pre-approved "Identify Friend or Foe" (IFF) frequencies.

If the UAV imagery transmitted is of public domain or public right-of-way and facilities, encryption of downlinked data may not be necessary. If, however, there is sensitive information contained, the value-added service provider will have to provide encrypted data transmission as part of the commercial imagery product delivered.

These requirements overlap with the regulatory and technology issues discussed below. National standards for identification and authority verification should be developed, and the technical means for detecting small, unauthorized ROAs by Air Traffic Control (ATC) towers or by urban Traffic Management Centers (TMC) could help overcome this barrier. Indeed, the latest Broad Agency Announcement (BAA) issued by the multi-agency Technical Support Working Group (TSWG) includes a task on developing small mobile radars able to detect UAVs.

MIT researchers have raised concerns that a terrorist could deploy for urban warfare a mother ship UAV controlling multiple "swarms" of small "children" UAVs designed to deliver bioagents or obtain surreptitious surveillance imagery. See article on Sept 22, 2003, "Regulatory Future for Unmanned Vehicles Pondered" at *www.nationaljournal.com/technologydaily* and articles by Professor Eric Feron at *web.mit.edu/feron/Public/www/publications.html*. While these are worrisome scenarios, it could be argued that some of these capabilities have not yet been developed even by the U.S. military, and it is unlikely that terrorists would resort to such delivery methods when simpler and less expensive vehicles are available.

3.3. Safety hazards

Commercial manufacturers of UAVs, as well as buyers and operators are concerned with potential costs of liability insurance, for first, second and third (public) parties. The FAA recognizes two types of adverse impacts requiring insurance coverage: in-flight aircraft collision hazards, and damage to property or harm to people on the ground resulting from a crash. There is little experience at present with various types of UAVs, although the larger and costlier ones usually have fail-safe modes. This means that, upon losing communications and control, UAVs must automatically return to launch site or deploy parachutes to minimize damages to any ground assets and life loss. On the other hand, an electrically powered- battery operated mini-UAV can do little damage on the ground in case of failure, and flies at altitudes far below those of commercial aircraft. However, one could envision an in-air collision with a commercial or personal aircraft in approach corridors used for take-offs and landing.

Depending on the size and the altitude of the UAV platform used for surveillance mission, driver distraction may lead to accidents. Clearly this is unlikely for Mini-UAvs and/or HALE UAVs, but may be an issue for intermediate sizes and low altitudes needed to obtain high- resolution imagery. On the whole, UAVs will be less obtrusive and have lower liability risks (see 3.4 below) than the noisy traffic helicopters or aircraft frequently used for such missions. The liability risk will be lower, since no pilot and passengers would be hurt in case of crash landing.

Some of these safety hazards can be prevented and effectively mitigated through design (e.g., redundant systems and fail-safe provisions). Another option is to transfer UAV damage and failure risk via insurance requirements (see 3.4 below).

3.4. Liability issues

Risk based aircraft insurance is currently available on the commercial markets based on long experience and statistical data on aircraft accidents and crash frequencies. The FAA sets minimum insurance requirements for commercial carriers, as well as caps to per passenger damages (mean "value of life" formulae). However, in the case of emerging UAVs, current reliability is lower (by factors of 10-100) than for manned systems: The 2002 DOD UAV Roadmap cited in 3.1 above presents military and Israeli UAV reliability figures compared to manned aircraft.

There are many types, sizes and propulsion options for UAVs, affecting the consequence severity of a failure: some carry conventional motors and fuels which can ignite on impact, others have solar, electric, or fuel-cell propulsion. Equipment failures in the payload also requires second party liability insurance between the owner/operator and the suppliers of equipment and services. Public federal, sate and local transportation agencies using a UAV to support their mission can self-insure, but some research groups may not acquire such insurance. Research and "success stories" are needed to encourage transportation officials to integrate UAVs into their operations without fearing liability costs. If a public agency or a public-private consortium sponsoring the UAV missions to protect the public good, can and will assume liability, this is not an issue. However, any commercial service provider proposing UAV-borne technology solutions should explicitly discuss liability coverage, based on some baseline and comparative risk assessment and plausible failure scenarios. Third party liability and business loss insurance should be part of the procurement package, to protect both the sponsor and the service provider

3.5. Privacy and civil rights issues

Issues concerning the legality of unauthorized surveillance even by Law Enforcement agencies and potential violation of civil liberties under the anti-terrorism provisions of Patriot Act have been publicized in the national press. A UAV equipped with high resolution video cameras for monitoring traffic patterns, or collecting surveillance imagery to ensure public security during a large public event (Olympics, ballgames at stadium, open air concert) could arouse concern about privacy violations and unauthorized surveillance.

Recent legal precedent suggests that the privacy arguments are valid only under specific circumstances. The Fourth Amendment of the U.S. Constitution guarantees citizens freedom from government spying as a civil right. In 1986, the Supreme Court affirmed in *Dow Chemical vs. U.S.* that aerial surveying was permissible in the context of standard remote sensing technology and was not an illegal "search." In 2001, however, in *Kyllo vs. U.S.*, the Supreme Court in a 5-4 decision declared that using forward looking Infrared (FLIR) technology to secure a warrant to search a residence suspected of growing marijuana was an illegal search and seizure and in violation of the Fourth Amendment.

The use of SUAVs as remote sensing platforms to monitor transportation infrastructure and operation must work within this legal framework. That is, aerial survey of transportation facilities owned by the public is within the authority of the government agencies responsible for these facilities. Using military grade high technology sensors to detect criminal activity, particularly when directed at private residences, is not appropriate by government agencies, in the opinion of the Court. The technology used in the MLB Scout 2, much of which can be purchased at commercial electronics outlets, meets the tests in *Dow Chemical*. In future demonstrations it may be advisable to use visible spectrum or popular low-light cameras (e.g. Sony's Night Vision) as SUAV remote sensing technology that is readily available to the general public, in order to avoid litigation in the deployment of SUAVs. The impact of anti-terrorist provisions of the USA Patriot Act have yet to be determined by the courts, and should be avoided in attempting to deploy SUAVs as remote sensing platforms in transportation.

3.6. Market and economic barriers

Frequently, market economics dictate adoption of innovative technologies: deployment of UAV-borne data acquisition payloads plus the data analysis and decision support value-added data products, plus the cost of staffing and training personnel must be cheaper than or comparable to competing alternatives over the lifecycle of the program.

Alternatives to UAV-borne platforms include manned airborne systems (helicopters, aircraft) or satellite data acquisition systems, as well as near-ground and ground based imaging and other sensors. One way to overcome this cost-competitiveness barrier is to develop partnering Institutional arrangements as discussed above share both risks and benefits. Public-public or public private partnerships (P^3) can offer cost savings through resource and results- sharing by several partners in system ownership and data.

Another way to overcome cost barriers is to select a UAV option with an already proven low cost, or known life-cycle cost. Such options were discussed in the AeroVironment and MLB presentations and include various mini, micro, or small UAVs. The lower cost-options are for turnkey UAV service providers to deliver the UAV platform with easy-launch and recovery, integrated communications and sensors payloads, and user-friendly control station hardware and software, including the value-added analysis and data products. In addition, low cost options must be available for training operating staff managing the UAV mission development and operations on demand, and for data processing, display, storage and analysis.

3.7. Institutional relationships

There are established models of institutional relations that encouraged the development of UAVs to date and can guide future deployment on a larger scale. However, most UAVs demonstrated to date have been developed under federal contracts for government agencies: DOD services, and NASA field centers with active UAV programs (Dryden, Ames, Wallops FF). Emerging federal players include: DHS (US Coast Guard and the Borders and Customs, and Transportation Security Administrations), which are now testing and evaluating the use of UAVs for security surveillance of borders, coastlines, ports and pipelines. Similarly TSWG is rapidly prototyping security technologies and systems for multiple homeland and national security agencies adoption. State transportation departments (like Caltrans, which developed the Aerobot, a tethered rotorcraft UAV for bridge cable inspection) and port authorities (like the Port of Long-Beach/Los Angeles) could jointly enter such arrangements with federal agencies interested in related information (e.g., port security, bridge integrity). Private companies (like Pacific Gas and Electric) could also develop broader partnership agreements with state and local agencies interested in pipeline integrity, safety and security, as well as with vendors interested in proving the value of their UAV/payload system.

The NASA presentation shared valuable "lessons learned" for institutional relationships that benefit all participants, based on HALE (e.g., Helios) and small UAV development, demonstration and research under the Environmental Research Aircraft and Sensor Technology (ERAST) program. One important lesson was that public-public partnerships with other agencies (NOAA, US Forest Service, FAA) are valuable and cost-sharing benefits also accrue. Public-private partnerships- using the NCRST model, which involve university and commercial technology companies and transportation agencies appear promising for delivering UAV knowledge sharing or cost-sharing benefits to all partners.

3.8. Technology and reliability/maintainability barriers

There are multiple technology solutions available now for addressing most of the other types of barriers discussed here, including safety and security. However, more sophisticated technology may adversely impact the economic and market penetration barriers. The chief technology challenges discussed above involve improving systems reliability and performance while keeping costs down: longer-life batteries and fuel cells to power UAVs for longer loiter duration and range; ability to survive high winds and adverse weather conditions (fog, snow, ice, hail, rain, tornadoes); sensors able to 'see' through clouds and smoke (radar, thermal infrared) and to complement video-imaging; higher quality imagery in a miniaturized, rugged package; redundant communication links; see and avoid technology options to ease access to NAS, as discussed above; electrical hardening (to withstand lighting strikes) higher data rates, communication security; automated data processing and pattern recognition algorithms, data visualization and decision support tools.

Any technology improvement must come at comparable or lower cost, if offered on a UAV payload; and it must not overcome a single specific barrier, while exacerbating another (e.g., redundant or more advanced technology may increase system front-end and operating cost, while decreasing liability insurance premiums). This means that the desirable UAV system (platform and sensors) technology solutions are highly constrained. This point was stressed by Dr. Wegener, in a summary slide on UAV technology needs: advanced sensors systems, high bandwidth data communication; Over the horizon (OTH) visibility "both compact and affordable", and technologies to ease access to and integration into the NAS.

4. Developing a UAV Agenda for the Future

4.1. Considerations

The workshop deliberations point to barriers that must be overcome, and suggest actions to further technical progress and to promote the use of UAVs. There are several items to consider in crafting a UAV technology deployment "roadmap" for transportation applications in the near future:

- There have been previous attempts at developing a deployment strategy, notably by standards development organizations (SDOs) and the federally funded initiative ACCESS 5, detailed in Section 3.1. A new strategy would need to build upon previous efforts and to complement them. To the extent that RSPA is interested primarily in transportation applications, there is an obvious need to identify a broad base of other interested parties and to pool their needs and resources into a common effort. Several NASA Centers (Dryden, Ames, Wallops) have active UAV research programs and offer excellent opportunities for synergy of the DOT NCRST university research consortia and associated Technology Application contractors with these plans.
- Previous major technology adoptions such as information technology (IT), intelligent transportation systems (ITS), geographic information systems (GIS), and remote sensing have developed strategies from which the UAV community could learn. In the U.S., the ITS strategy in particular could be traced to a set of initiatives and organizations (ITS America and the "National ITS Architecture" documents) that were influential in unifying thinking about the technology, and developing support for its implementation. UAV proponents would need to develop a similar organizational structure, albeit on a different scale.
- It could be argued that UAV technology involves more non-technical barriers than do the IT/ITS/GIS technologies listed above, and a strategy would have to consider at the very least

- Consultation with potential users, and identification of application niches where the unique capabilities of UAVs are critical, and the risks and barriers of UAVs are minimal or exceeded by potential benefits. For example, applications where SUAVs meet the spatial and temporal resolution requirements for identification of vehicle types and container sizes (*esp.* monitoring of traffic and parking), should be pursued.
- Technical development: outstanding research needs on platforms, sensors, post-processing of sensor data, etc, and funding mechanisms to support this research, demonstration, test and evaluation (RDT&E) effort .
- Outreach, education and communication (particularly directed at state and local government operating agencies).

4.2. Recommended actions

Based on the sections above, the following priority actions are recommended:

1. Review ACCESS 5 and other previous initiatives. This is envisioned as a 3 to 6 month, RSPA-sponsored activity, to link NCRST activities with those of other agencies.
2. Broaden the base of NCRST involvement in UAVs to include NASA, FAA, DOD, DHS, major SDOs, and other players involved in UAV strategy development, including many of the attendees at the UAV2003 workshop. Again, this is a RSPA/NCRST action, that can run concurrently with the ACCESS 5 effort.
3. Identify persuasive and convincing applications ("killer apps") where the benefits of UAVs overwhelm the costs and risks, and it can be argued that deployment is imperative and urgent. Such applications should ideally cut across a broad swath of areas of interest, e.g. shipping and railroads, homeland security, agriculture and health. This is an approximately 1-year, synthesis-like activity that requires interviews with a variety of potential users, and analysis of needs, costs and benefits across agencies.
4. Organize one or several technology demonstrations (see section below). RSPA could lead this, with the cooperation of NASA, FAA, DOD, DHS, local governments and port authorities.
5. Develop a web-based compendium of UAV success stories. This is already under way, and will be hosted by NCRST-Infrastructure, *www.ncgia.ucsb.edu/ncrst*
6. Identify and seek the advice of key individuals in other technical deployment efforts (IT, ITS, GIS) to develop strategies to gain financial and political support. In particular, involve national organizations of transportation agencies, such as AASHTO, APTA, APWA, NACO, and CTAA with access to transportation operating entities at the state and local level.
7. Identify key areas where further technical development is required, and establish the political and institutional bases of research funding. RSPA, in cooperation with other DOT administrations (FAA, FHWA, FRA, MARAD, NHTSA) and other Federal departments (DHS, DOD, NAS/NSF) are the most likely organizations to take the lead.
8. Assuming that UAV technologies will be deployed to some degree in the near future, identify personnel requirements and develop preliminary curriculum recommendations for workforce development.

Items [1]–[3] are relatively short term and can be accomplished within a year, while the others are larger and continuing, longer term tasks. With the exception of [7], they could be contracted to one or more NCRST institutions, with the involvement of other public and private agencies.

4.3. UAV technology demonstrations to quantify benefits

A difficulty with needs analysis for new technologies is that potential users are not well versed with technical capabilities of a system, and needs tend to be under-specified. One possible element in a deployment strategy would be a well-publicized technology demonstration of UAV capabilities, which permits quantification of benefits. An example discussed at the workshop was a UAV flight over the Los Angeles port area, combining applications in port security, and marine and ground traffic management. While it would require careful planning to ensure a broad base of support, there are a number of reasons why a flight in the Los Angeles area could be particularly successful:

- The Los Angeles-Long Beach ports handle a huge volume of container traffic, roughly 10-15% of the nation's overseas trade. Ports are obvious terrorist targets, and administrators are receptive to new technologies for surveillance and management. The purpose of a UAV demonstration would be to demonstrate the combination of sensor capabilities (spatial and spectral resolution) and near-real time turnaround of data and analysis. For example, a ship carrying suspicious cargo could be "sniffed" while still at a distance from the port, and change detection could help to identify unusual developments soon after they occur.
- The Los Angeles-Long Beach port facilities were built prior to the expansion in Far East trade and they struggle to cope with today's traffic volume. There is a need for better management of existing facilities capacity, as well as for further expansion and reconstruction. Specifically, I-710, which serves the ports and carries a large proportion of truck traffic, is urgently in need of upgrade. Urban development in the south Los Angeles and the multi-modal Alameda Corridor areas are particularly challenging due to the port activity and the socio-economic nature of the area. Local governments and developers in the area would have considerable interest in a technology that can deliver up-to-date imagery.
- On the supply side, a number of organizations were identified, including state and local government agencies, universities and research laboratories, UAV service vendors, private consulting firms and transportation and utility firms in southern California, that would probably be willing partners on a demonstration project.

The justification for the choice of Long Beach-Los Angeles is intended not to single out Los Angeles, but to describe the breadth of applications that could be addressed in a single UAV demonstration. There are of course other sites with similar potential, and ideally a number of these should be chosen judiciously across the nation in partnership with NCRST consortia, to ensure that benefits accrue to multiple transportation and other (security, emergency managers, resource agencies) stakeholders. Examples are Critical Transportation Infrastructure (CTI) facilities: LNG ports and offshore oil terminals (e.g., Gulf area, Alaska), and multi-modal nodes in close proximity (Boston Harbor, abutting the Central Artery Tunnel, the Logan Airport, a major container terminal and fuel tank farm.

5. Concluding Remarks

The Santa Barbara workshop brought together a number of high profile organizations, both vendors and potential users of the technology, and demonstrated a high level commitment of these organizations to UAV deployment to benefit transportation and synergistic uses. While this was a significant milestone in the development of a transportation and UAV community of users, it must be seen as the beginning of a broader process of cooperative engagement and program planning that combines applied research, technology development and commercial applications development.

The most encouraging aspect of the workshop was that while it documented the barriers in detail, it reached beyond them and identified solutions and initiatives (as detailed in the previous section): to develop a set of compelling applications, to demonstrate and document the successes of the technology, and to promote the cause within funding agencies and the government. The outcome is a realistic action plan.

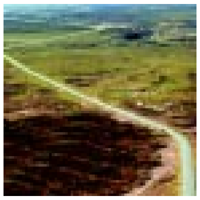
Appendix A — Workshop Attendees

Beverley Adams, ImageCat, Inc.
Randy Albertson, NASA/Dryden Flight Research Center
Bob Battersby, California Department of Transportation
Ike Bayraktar, AeroVironment Inc
Aviva Brecher, DOT/RSPA Volpe Center
Rick Church, UC Santa Barbara
Dick Dallas, SiWave, Inc.
David Glackin, The Aerospace Corporation
Mike Goodchild, UC Santa Barbara
David Grilley, SRA Adroit C4ISR Center
Martin Herold, UC Santa Barbara
Mark Humpherys, Space Dynamics Laboratory
Hank Jones, MLB Company
Yogi Krikorian, The Aerospace Corporation
Jonathan Lamb, US Department of Homeland Security
Bill Lyte, Tetra Tech Inc
Rick Marsh, The Boeing Company
Bob Meline, California Department of Transportation
Pitu Mirchandani, University of Arizona
Hossein Monfared, US DOT
Val Noronha, UC Santa Barbara
Mark Nugent, The Boeing Company
Donald Price, Pacific Gas & Electric Company
Steve Wegener, NASA Ames Research Center

Unable to attend, associated with the effort
Larry Harman, Bridgewater State College
Mark McCord, Ohio State University
Stephen Morris, MLB Company

Contact details for attendees are available at the meeting web site:
www.ncgia.ucsb.edu/ncrst/meetings/uav2003

PARTNERSHIP PROJECTS FOR MULTIMODAL TRANSPORTATION APPLICATIONS



ENVIRONMENTAL IMPACT FOR MULTIMODAL CORRIDOR PLANNING CONSORTIUM

Mississippi State University, Lead
www.ncrste.msstate.edu

Dr. Roger King, Consortium Manager
Dr. Charles 'Chuck' O'Hara, Consortium Coordinator

Streamlining the decision process for corridor planning and relocation

- New solutions for transportation relocation and corridor planning.
- Using raster and vector geospatial data in corridor planning.
- Relocating the CSX railroad in the Mississippi coastal corridor.
- Assessing urban growth in coastal corridors.
- LIDAR applications for terrain mapping and hydrologic analysis.
- LIDAR application for alignment optimization.
- Hyperspectral data for wetland vegetation mapping and analysis.
- Geospatial data fusion for environmental assessment.
- Analysis of growth impacts on urban watersheds.
- LIDAR measurements of air pollutants and air quality modeling.
- Assessing urban growth and transportation impacts .
- Mapping resources and data libraries for environmental assessment.
- User needs for geospatial technologies.

Mississippi State University
University of Alabama in Huntsville
University of Mississippi
Auburn University
USRA
NASA Marshall Space Flight Center
Digital Globe
Intermap Technologies Corp.
Earth Data Technologies, LLC
ITRES Corporation
Virginia DOT
EarthData
ICF Consulting
Washington State DOT
Veridian Systems Division

DISASTER PREPAREDNESS AND LIFELINES SECURITY CONSORTIUM

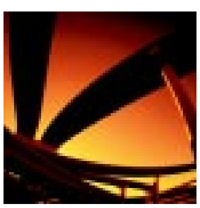
University of New Mexico, Lead
www.trans-dash.org

Dr. Stanley Morain, Consortium Manager
Dr. Richard P. Watson, Consortium Coordinator

Hazards, disasters and security response

- Planning evacuations in emergencies.
- Detecting damaged bridges for emergency response.
- Planning community evacuations for large populations.
- Tools for managing highway bridges.
- Transportation hazards consequence tool.
- Geospatial data and toolkits for transportation applications.
- Rational Mapper—a tool for processing high-resolution images.
- Assessing pipeline and airport safety using LIDAR data.
- Hyperspectral analysis of urban surface materials.
- Evacuation routing tools to reduce evacuation times.
- Evacuation simulations for communities trapped in a bottleneck.
- Mapping potential damage due to land subsidence.
- Sensing technologies for planning pipeline corridors.
- Managing rural roads in Indian reservations.
- Calculating mileages for highway performance monitoring.
- Safety obstructions at Municipal Airport.
- Weather-related road hazards assessment.
- High-resolution satellite data updates E-911 road information.

University of New Mexico
University of Utah
Oak Ridge National Laboratory
George Washington University
York University
ImageCat, Inc.
DigitalGlobe
AERIS Inc.



INFRASTRUCTURE ASSET MANAGEMENT AND SAFETY CONSORTIUM

University of California Santa Barbara, Lead
www.ncgia.ucsb.edu/ncrst

Dr. Michael Goodchild, Principal Investigator
Dr. Val Noronha, Project Director

New solutions for infrastructure asset management

- Responding to security threats, hazards and disasters.
- Evacuating a small neighborhood: infrastructure adequacy.
- Meeting the challenge of inventory assessment.
- Urban hyperspectral sensing and road mapping.
- LIDAR applications for highway design and construction.
- LIDAR for engineering design.
- BridgeView – a tool for bridge inventory and assessment.
- Security siting of off-port inspection facilities.
- Tools for managing highway bridges for the National Bridge Inventory.
- Aviation infrastructure planning and development support.

University of California, Santa Barbara
University of Wisconsin-Madison
Iowa State University
University of Florida
Digital Geographic Research Corporation
Geographic Paradigm Computing Inc.
Florida DOT
University of Massachusetts
Orbital Imaging Corporation
Tetra Tech, Inc.

MULTIMODAL TRANSPORTATION FLOW CONSORTIUM

Ohio State University, Lead
www.ncrst.org

Dr. Joel L. Morrison, Consortium Director
Dr. Mark R. McCord, Consortium Research Coordinator

Integrating remote sensing for transportation operations

- Real-time bus information system with image backdrops.
- Applications for traffic operations.
- Traffic measures using satellite and airborne imagery.
- Determining highway level of service using airborne imagery.
- Improving freight flow flow management.
- High resolution georeferencing from images for traffic flow.
- "Bird's-eye" views of networks for mitigating urban congestion.
- Exploring LIDAR applications for traffic flow.
- Pioneering traffic data collection from UAVs.
- Automated vehicle tracking from airborne video.
- UAV applications for multi-modal operations.
- Airborne Data Acquisition System (ADAS) for traffic surveillance.

The Ohio State University
George Mason University
University of Arizona
GeoData Systems Inc.
TerraMetrics Inc.
Veridian
Grafton Technologies
Technology Service Corp.
Bridgewater State College