THE ROLE OF UNMANNED AIRCRAFT SYSTEMS (UAS) IN DISASTER RESPONSE AND RECOVERY EFFORTS: HISTORICAL, CURRENT, AND FUTURE

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A wide range of legislation has been proposed or put into place that restricts the use of unmanned systems. These actions by legislators and regulators will stifle the growth of this technology and the associated surrounding industry. The largest obstacle to the proliferation of UAS in the U.S. is the FAA. The FAA has designated the location of six test sites that are anticipated to allow for less restrictive and formative research to assess the technologies that the FAA has claimed need to exist in order to integrate UAS into the NAS. Further complicating the adoption of UAS for beneficent causes is the plethora of local and state legislation and regulation. Whilst many state restrictions do have built-in caveats to potentially allow for disaster support utilizing UAS, not all are so explicit. All of these actions make the adoption of UAS in disaster areas more complex and may sway associated agencies away from purchasing UAS for these uses in the future. This research outlines historical uses of UAS to provide basis for the adoption in disaster relief. Examples of past use of unmanned systems in exigent event response are provided including post-hurricane rescue, wild fire monitoring, and landslide disaster relief. An example of missed opportunities with UAS, the Boston Marathon bombing is also outlined. Current UAS usage in first response is explained including types of platforms and sensors that show promise in such operations. Future considerations for UAS adoption in disaster efforts are outlined.

BACKGROUND

The presence of unmanned vehicles conjures up images of combat capable killer drones armed with a variety of missiles whose sole purpose is to kill and destroy. In reality, most of the technology developed for unmanned aircraft is designed for intelligence, surveillance and reconnaissance (ISR), and this technology can be easily adapted and applied toward peacetime uses that benefit civilian populations. The major delays in the implementation of unmanned aircraft systems within the United States has been on the regulation side of the house with concerns revolving around safety, integration into the National Airspace System (NAS), and privacy issues. The development and degree of sophistication of technology related to unmanned aircraft systems (UAS) has been unparalleled in the past decade, and the realization of potential beneficial uses of these systems has grown at a phenomenal rate.

The introduction of any new technology or procedure into the NAS requires a comprehensive safety analysis before the FAA can allow the change. This is understandable since the mission of the FAA is to regulate and oversee all aspects of American civil aviation, and has

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built its heritage and reputation on promoting safety within the NAS and throughout the world. The FAA has the authority to issue special authorizations for use, but these authorizations are limited. The current access to the NAS, outside of special-use airspace, is through the certificate of authorization process or the experimental airworthiness process.

One of the issues with obtaining a CoA for legal operation of a UAS in disaster response and recovery efforts is the need to provide a detailed description of the intended flight operation, including the classification of the airspace to be used. This information is often not specifically known prior to the occurrence of the disaster. For example, in disaster and recovery operations, many times the location and classification of airspace to be used is not known prior to the occurrence of the event. Additionally, the extent of local, county, state, and federal response agencies involved is not known until the occurrence of the event. Not knowing this information, which is required as part of the CoA application process, makes it almost impossible to obtain permission from the FAA to legally operate a UAS as part of a disaster response and recovery effort even though use of this technology can easily provide critical information to the agencies responsible for search and rescue operations (SAR) and damage assessment.

Privacy issues are also a major concern for the American public. The United States Constitution, specifically the Fourth Amendment to the United States Constitution, prohibits unreasonable search and seizures and requires that any action of this nature be supported by a judicial review showing probable cause to conduct such activity. UAS technology now provides access to areas that were once not accessible by law enforcement, thereby raising the question of whether use of UAS technology by law enforcement agencies is legal, and whether existing laws and regulations should be modified to address the use of UAS technology and restrict the use of that technology on citizens of the United States.

Recent actions by the American Civil Liberties Union (ACLU) has generated a great deal of public interest and discussion in the area of privacy related to the use of UASs, and this public interest and discussion has resulted in some states passing legislation restricting the use. Unfortunately, there is no consensus as to what UAS legislation should include or what restrictions on use of UAS technology is reasonable. Most legislation passes a combination of restrictions on the use of UAS technology and image capturing capability while allowing some legal use and exemptions for legitimate law enforcement and commercial uses.[1]

HISTORICAL USE AND BENEFITS

The role and usage of UAS has grown significantly in the U.S. since their adoption as aerodynamic models, test beds, and aerial munitions in the early years of aviation (i.e., 1890s to 1918).[2] Eventually, after the baseline technology was advanced, the roles of UAS were expanded to include use as aerial targets, weapons delivery platforms, communications relays, target designators, and ISR gathering assets.[3, 4] While the application of UAS has steadily increased over the years, the full extent of reliability and functionality was not realized until the 1990s.[5] During operations Desert Shield and Desert Storm, U.S. forces flew a significant number of missions using UAS, which represented the first wide-scale use of this technology.[6, 7, 8] These aircraft ranged in size from the group one sized FQM-151A Pointer, launched by hand, up to the group three RQ-2 Pioneer, requiring specialized support equipment for launch and recovery.[9]

The use of UAS in military conflicts of the 1990s supported the capture of time sensitive intelligence and data that could be used by military leadership in their decision making process, without subjecting a manned aviator to the risk of flying in an operational theater.[10] Information could be obtained faster, from dangerous environments, with less risk to valuable assets and pilots. The result of this wide-scale use of UAS demonstrated their value, leading to the investment of funding to further develop and refine the associated technology and operational processes.[11]

Advancement in the underlying and related technology, coupled with need, has led to the identification of wider application and utility of UAS.[12] As the increased or improved capabilities associated with new technologies or the boundaries of existing technologies are discerned, the utility and capability of UAS also increase. [13] While the majority of historical UAS application has stemmed from military/tactical uses, the technology has migrated to the civilian and commercial sectors. The resulting benefits of such migration include the ability to provide increased security, productivity, and efficiency, enhanced mobility and response, and improved access to perform disaster assessment, infrastructure inspection, and environmental protection.[14, 15]

APPLICATION ISSUES

Historical, Current, and Missed Applications

The application of UAS for the sake of saving lives and assessing damage has been advocated my numerous government organizations and researchers.[16, 17] While there have been several high profile cases where UAS have been used in disaster relief in other countries, emergency responders in the U.S. have been hesitant to use them in such cases due to regulatory and legislative restrictions.[18, 19] There are however, some examples of historical and current usage domestically. Also, UAS stakeholders have provided examples of missed cases in which UAS could have dramatically assisted in emergency events.

California Wild Fires. On multiple occasions in the past, the State of California has utilized UAS in attempts to monitor and fight wildfires. In 2011, a UAS was used to map fire activity and damage.[5] As recently as 2013, a Predator UAS from the 163rd Wing of the California Air National Guard was used to provide real-time imagery to firefighters in order to assist in planning and direction of assets in a 301 square mile fire within Yosemite National Park.[20] Of course, military platforms do not face the restrictions with which operations that smaller, non-military UAS users must conform. In fact, other California UAS operators have been cautious to launch their platforms even in face of threatening fires because of FAA restrictions.[21]

Post-Hurricane Uses. Two UASs from the University of South Florida were deployed following the landfall of hurricane Katrina in storm damaged communities in Mississippi. A four foot long fixed wing platform was used to provide an overview of damage. A helicopter UAS was used to zoom in on a smaller scale, looking at rooftops and within windows. This permitted first responders to confirm there were no survivors in the area threated by the Pearl River flood waters. This allowed rescuers to more effectively deploy assets to other locations.[22] Three days following the landfall of hurricane Wilma, a micro UAS was coupled with a unmanned water surface vehicle to assess damage to seawalls, piers and to identify submerged debris.[23]

Washington Landslide. In March of 2014, a massive landslide occurred burying a community near Arlington, Washington. In addition to the devastation brought by the slide, debris blocked a river potentially making things worse with the threat of massive flooding. To assess the damage, the status of the river, and to look for survivors a small UAS was deployed. The system was able to provide real-time data to rescue personnel through video feed and by taking photographs.[24]

Boston Bombing. Although there are many cases in which UAS use for disaster relief could have been helpful, one of those receiving a tremendous amount of media attention was the bombing of the Boston Marathon in 2013. According to Clark, "Police, lawmakers and advocates are questioning whether police drones could have found the suspects faster."[25] Numerous experts and law enforcement personnel believe that the manhunt for those responsible would have been more timely and organized with the inclusion of UAS. Moreover, if UAS were able to monitor such events, they may act as a deterrent and, in the worst case, assist in identifying guilty parties.[26, 27]

Issues Preventing or Limiting Use

The primary restriction to UAS operations for any non-personal (hobby) or larger platforms comes from the FAA. Currently, any other type of UAS operation – academic, law enforcement, commercial, disaster relief – is limited by FAA mandates. If an individual wants to operate a non-personal UAS, they must apply for a Certificate of Authorization (COA) with which the FAA has not been reliably forthcoming. As of March 2014, only public agencies are eligible to apply for a COA. Alternatively, a user can apply for a special airworthiness certificate but these provide limited scope of use. Thus it is impossible for first responders to "legally" utilize UAS in their efforts except in the case of a sponsoring military agency. Yet this means that disaster responders have limited flexibility about quickly and effectively dealing with time sensitive events.[28]

Additional state and local legislation has surfaced to limit UAS usage. As of 2014, 43 states had considered or passed UAS-restrictive legislation. More than 70% of the passed legislation allow provisions for UAS use in exigent circumstances such as emergency response. Additionally, more than 80% of those passed permitted UASs when a warrant was issued. Many municipalities have also brought forth constraints to UAS. Charlottesville, Virginia has a "drone-free zone" and a moratorium on the purchase of UAS by the city. Other cities and counties have adopted restrictions on weaponized UAS, UAS prohibitions, and limits to purchases of UAS by government or law enforcement. However, many of these motions have exemptions for UAS being flown for exigent circumstances.[29]

More resistance to UAS adoption stems from privacy concerns. When the City of Seattle attempted to add UAS to their police force, protesters forced the Chief of Police to abandon the pursuit indefinitely.[30] There has been a significant amount of public concern voiced about UAS data collection, even if unintentional, during their use even in disaster relief or other virtuous tasks. This has prompted legislators and local representatives to pursue the aforementioned legislative actions. Also, prominent groups such as the American Civil Liberties Union (ACLU) and Code Pink have been vocal about privacy protection from UAS. Even the FAA has faced pressure about addressing the privacy issue, which they then included privacy protection language in the recently released test site plan which will allow UAS testing for their integration into the National Airspace System.[31]

CURRENT DISASTER RESPONSE APPLICATION

Uses of UAS for the civilian sector are numerous and the list is growing daily. The trend in military UAS applications is to replace manned missions that are typically classified as "dull, dirty and dangerous.[32] The terms "dull, dirty and dangerous" not only describe a significant part of warfare activity, but can also be applied to many tasks where UAS technology can be most useful, including but not limited to things such as pipeline monitoring, agricultural and crop-dusting applications, wildfire aerial assessment, and disaster response and relief efforts.

UAS technology is uniquely suited for ISR operations due to a wide variety of sensors and payloads available for military and civilian use. Sensors are usually designed to collect information or data from the aircraft or environment, whereas payloads are usually designed to leave the aircraft. Examples of sensors may be video cameras, infrared cameras, multispectral cameras, or aircraft sensors (altitude, airspeed, temperature, etc.), whereas examples of payloads may be crop-dusting pesticides, water for fighting fires, or as is the case with military applications, armament. However, payloads can also refer to a collection of sensors combined into one unit such as a suite of sensors (infrared cameras, high resolution video cameras, etc.). Today, the term sensor and payload are often used interchangeably.[33]

One of the most redeeming features of a UAS used in disaster response and recovery efforts is the ability of the UAS to transmit information from sensors and payloads back to the ground control station (GCS) for processing. The ability of the UASs to fulfill their missions depends in large part upon the communications link between the UAS and the GCS.[34, 35] These two factors allow UAS units (UAS and GCS) to enter an affected area quickly while leaving the human component behind in a safe location to process information and coordinate response and recovery activities. Sending the UAS into the hazardous area to perform the missions related to damage assessment and search for stranded individuals in need of assistance can be performed much sooner than normally possible if the technology were not present and available. This allows enhanced situation awareness for rescue and response personnel and pinpoint focusing of resources where needed instead of blanket coverage and inefficient rescue operations.

CONSIDERATIONS FOR FUTURE APPLICATION

There are several significant concerns and challenges that may restrict the operation and application of UAS to support disaster recovery and response. These concerns and challenges include gaining access to airspace,[36] ensuring safety and privacy,[37] and optimizing data capture and analysis. Until these issues are better understood, with possible methods to mitigate identified, the potential of UAS to support disaster recovery and response efforts may not be fully achievable.

A few recent research topics associated with UAS technology exhibit potential applicability and benefit to resolve some of these issues. These subjects include unmanned system teaming,[38] improved algorithms (e.g., compression, data-scanning, non-iterative, segmentation, classification, and labelling),[39, 40, 41] adaptive training,[42] and improved automation.[43, 44] Further exploring these avenues of research may provide additional capabilities and performance to better support the future execution of UAS disaster recovery and response missions.

CONCLUSIONS

The adoption of UAS in disaster and recovery efforts shows excellent promise to assist first responders to support in the most comprehensive possible ways. By giving these individuals difficult to attain or presently unavailable data, first responders can apply UAS to expedite their efforts in order to save property and lives in a safe, efficient, and effective manner.

Unfortunately, the current regulatory environment hampers their use. It is critical that UAS stakeholders continue their efforts to attempt to provide regulating agencies and legislators the extremely beneficial attributes of UAS in the ability to provide critical data to disaster and recovery efforts. Examples such as the Boston Marathon bombing point to missed opportunities that could have benefitted from the inclusion of UASs.

Once the regulatory issues are resolved and the FAA provides a framework for reasonable use of UAS, such should allow for constructive and beneficent UAS operations such as those that assist first response efforts. The potential of UAS to help in disaster and recovery efforts cannot be underestimated and theoretically can revolutionize the data collection and observation capabilities in situations currently handicapped by the lack thereof. UAS have the capability to transform the way disaster relief is handled – let us hope that the obstacles are removed so that rescue personnel can leverage their abilities to save lives.

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National Aeronautics and Space Administration

UAS Integration into the NAS:

Phase 1 Human Systems Integration Activities

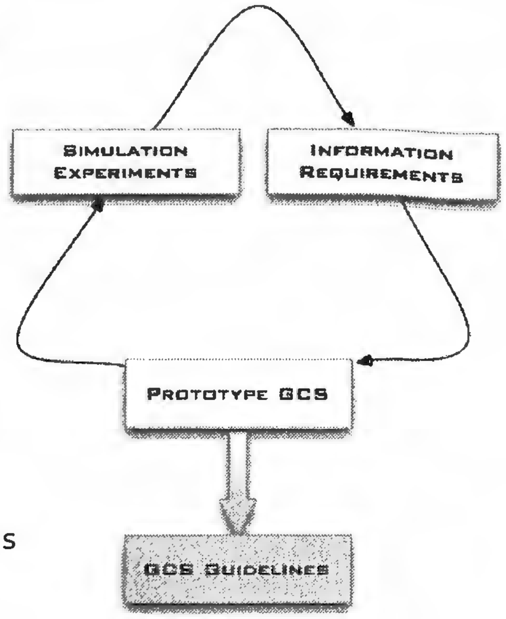
AUVSI's Unmanned Systems 2014

13 MAY 2014

www.nasa.gov

Human Systems Integration (HSI) Overview

- Objectives:
  - I. Develop GCS guidelines to operate in the NAS
  - II. Develop a prototype display suite within an existing GCS to:
    1. Serve as a test bed for UAS pilot procedures and displays
    2. Provide a database to support guidelines development
    3. Provide an instantiated proof of concept for those guidelines
- Technical Activities:
  - o. Information requirements analysis to identify the minimum GCS information to operate in the NAS
  - o. Simulation experiments to examine:
    - UAS pilot performance under various operating conditions and GCS configurations
    - The impact of nominal and off-nominal UAS operations on Air



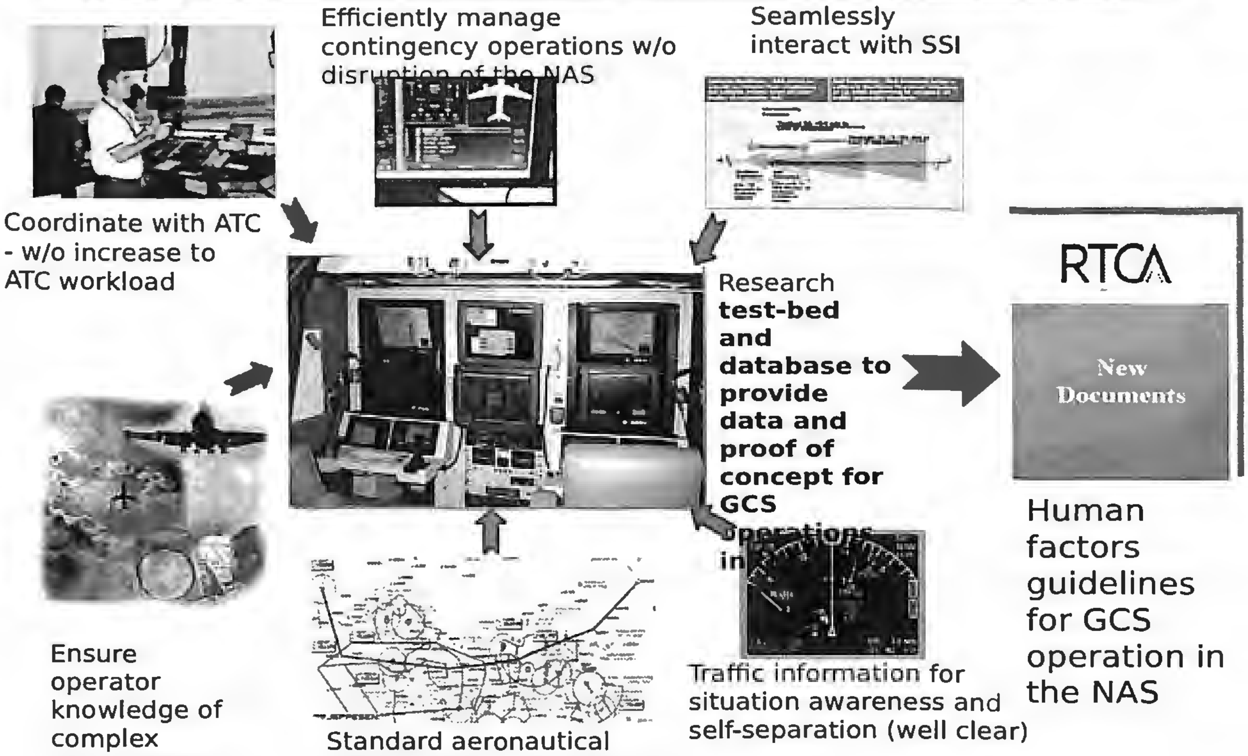
SIMULATION EXPERIMENTS

INFORMATION REQUIREMENTS

PROTOTYPE GCS

GCS GUIDELINES

Human Systems Integration



Efficiently manage contingency operations w/o disruption of the NAS

Seamlessly interact with SSI

Coordinate with ATC - w/o increase to ATC workload

Research **test-bed and database to provide data and proof of concept for GCS operations in**

Human factors guidelines for GCS operation in the NAS

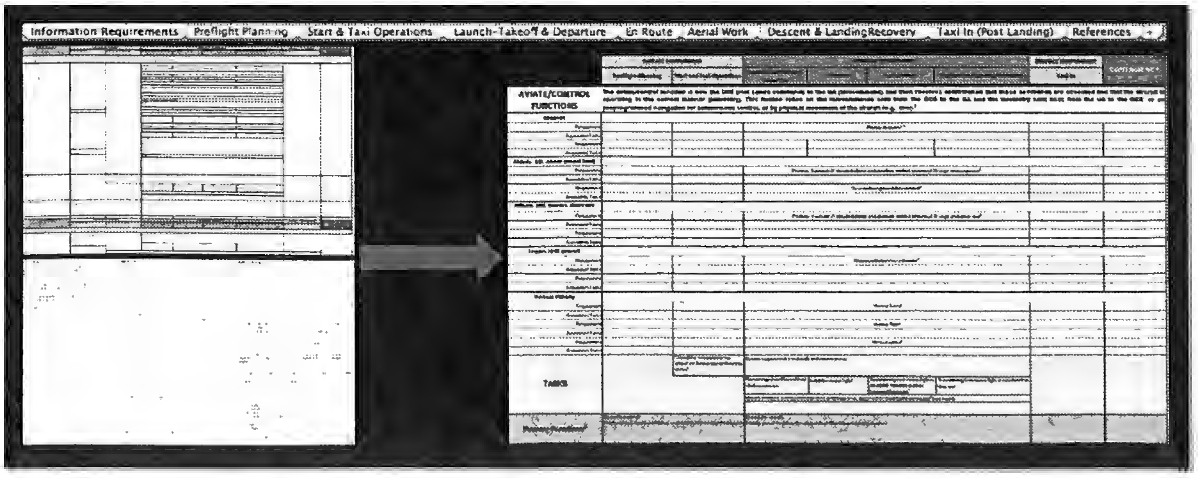
Ensure operator knowledge of complex airspace and rules

Standard aeronautical database for compatibility

Traffic information for situation awareness and self-separation (well clear)

Information Requirements Analysis

- Parallel Information Requirements Analyses:
  - Phase of Flight
  - Functional (e.g., aviate/control, manage, avoid, etc.)
  - Evaluation of existing Federal Aviation Regulations (FARs)
- Combined into a single, searchable database
  - Primary reference for development of prototype GCS displays and guidelines



UAS Pilot Performance

- Key Issues for UAS Pilot Performance:
    - Ability to perform comparably to pilots of manned aircraft (transparent to ATC)
    - Traffic display elements that support ability to maintain self-separation
    - Design of, and levels of automation in, command and control/navigation interfaces
- Simulation Experiments Examining UAS Pilot Performance:
    - Part Task Simulation 1 – Baseline Compliance
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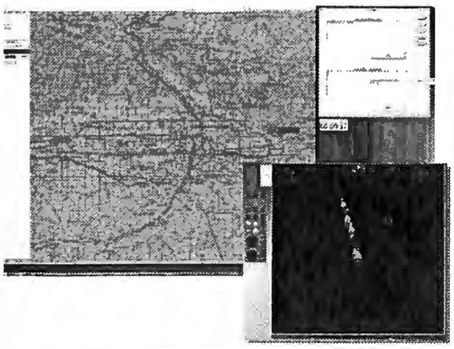
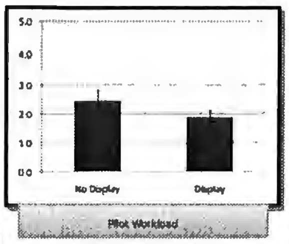
UAS Pilot Performance

Part Task Simulation 1: An Examination of Baseline Compliance

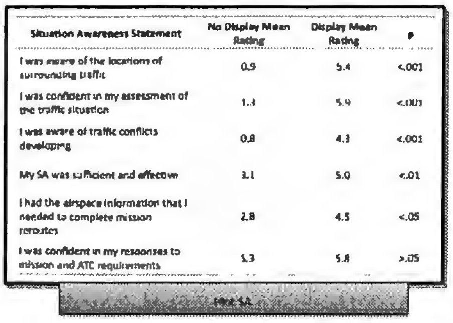
➢ **Objectives**:

1. Examine baseline compliance of UAS operations in the current airspace system
2. Examine the effects of introducing a traffic display into a UAS ground control station on pilot performance, workload and situation awareness





Pilot Workload



Situation Awareness Statement	No Display Mean Rating	Display Mean Rating	p
I was aware of the locations of surrounding traffic	0.9	5.4	<.001
I was confident in my assessment of the traffic situation	1.3	5.9	<.001
I was aware of traffic conflicts developing	0.8	4.3	<.001
My SA was sufficient and effective	3.1	5.0	<.01
I had the airspace information that I needed to complete mission reroutes	2.8	4.5	<.05
I was confident in my responses to mission and ATC requirements	5.3	5.8	>.05

Pilot SA

Main results/conclusions:

- ATC reported appropriate and immediate compliance by UAS pilots, and sufficient knowledge of the airspace and required procedures
- No effect of traffic display on maintenance of separation in Class A airspace
- Potential benefits to both Pilots and Controllers when a traffic display is present in the GCS
    - significantly higher pilot SA on several dimensions
    - significantly lower workload for pilots when communicating with ATC

UAS Pilot Performance

Measured Response A: UAS Response to ATC Clearances

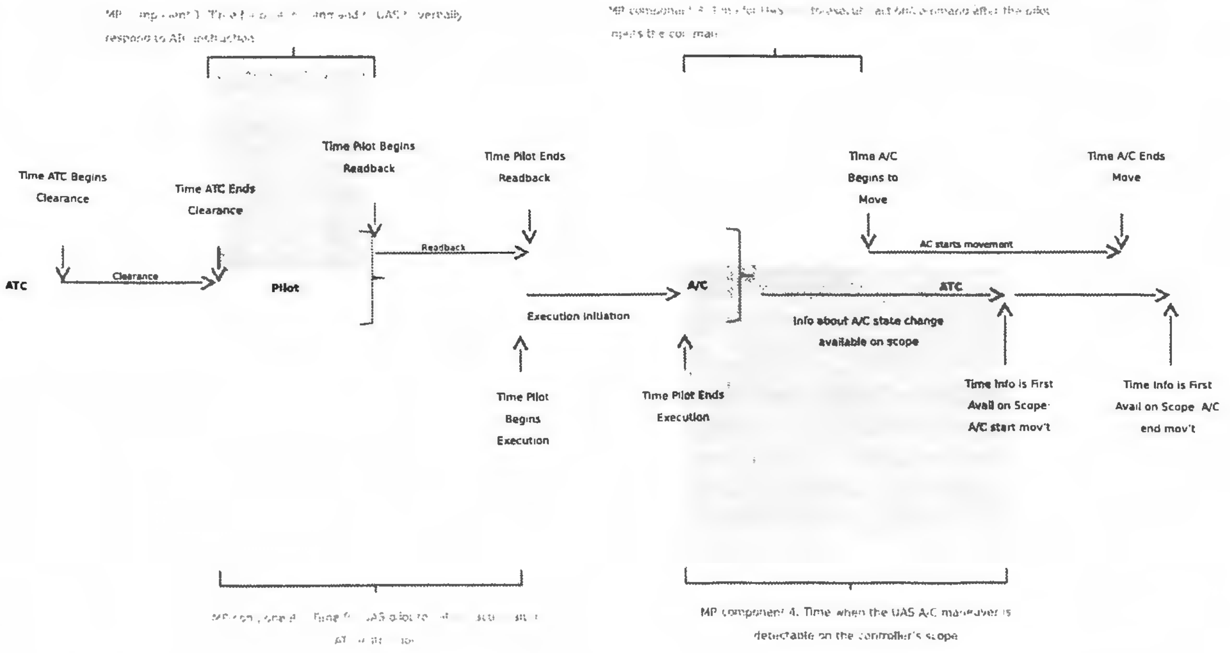
- **Objectives**:
  1. Demonstrate the ability to capture measured response (MR) components
  2. Measure UAS pilot verbal response and execution latencies in response to standard ATC commands and clearances
  3. Obtain ATC acceptability ratings of these latencies

	Clearance Type					
Measures	Crossing Restriction	Direct To	Route Amend-Altitude+ Traffic	Route Amend-Heading	Route Amend-Altitude	Traffic Alert + Immediate Turn
MR1 Time (in seconds)	2.64	2.71	2.43	2.71	2.07	2.86
MR2 Time (in seconds)	7.61	7.29	1.18	4.86	2.64	1.54
MR3 Time	Not captured because event occurs instantaneously in MUSIM					
MR4 Time (in seconds)	4.43	1.16	4.00	3.02	4.21	2.48
Pilot Workload Rating (1= Very low; 7 = Very high)	2.25	2.2	1.61	1.63	1.45	1.79
ATC Acceptability Rating (1= Not Acceptable; 7 = Highly Acceptable)	6.10	6.15	6.55	6.39	6.38	6.51

Main results/conclusions:

- MR components can be extracted for many ATC clearances along with their acceptability ratings
- Different MR components can occur in parallel/overlap with other MR components. As a result, the entire MR cannot simply be computed by adding up all the MR

UAS Pilot Performance



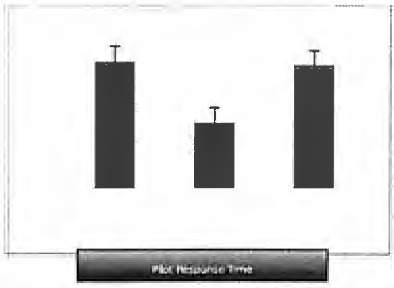
Measured Response A Identified Four Key Measured Response Components

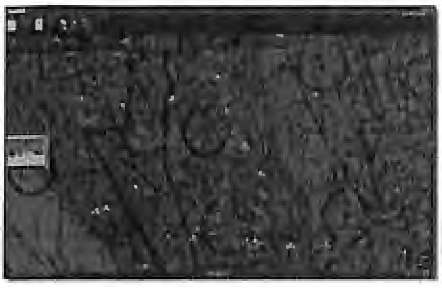
UAS Pilot Performance

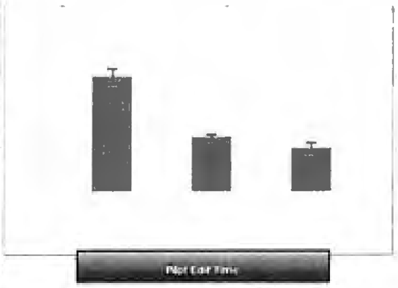
Full Mission 1: The Effect of GCS Control Mode Interfaces

➢ **Objective**: to examine the effects of three different command and control (C2) interfaces on UAS pilots' ability to respond to ATC commands:

1. Waypoint-to-Waypoint only (WP; baseline)
2. Autopilot (quick input interface)
3. Manual (stick and throttle)







Main results/conclusions:

- Waypoint-to-waypoint control mode demonstrated significant deficits in all of the pilot measured response components compared to AP and M
- AP and M had significantly shorter compliance times overall than WP
- These results provide the initial database of expected pilot response time distributions, which will be critical to determining the Minimum Operational Performance Standards for UAS in the NAS
  - Acceptability of C2 interfaces depends on the allowable response times given equipment performance specifications (i.e., sensors, aircraft performance, etc.)

ATC Performance

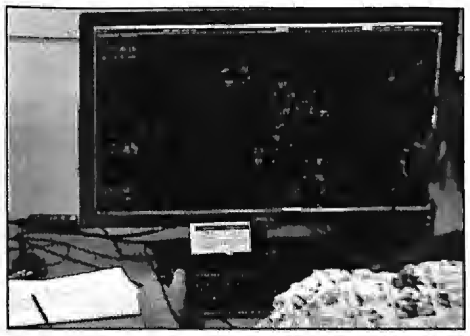
- Key Issues for ATC Performance
  - Lost link and other UAS-specific contingency procedures
  - Command and control and voice latencies
- Simulation Experiments Examining UAS ATC Performance:
  - Part Task Simulation 3 – Contingency Management
    - Fern, L., Rorie, R. C., & Shively, R. J. (in press). UAS contingency management: the effect of different procedures on ATC in civil airspace operations. *Proceedings of the 14th Annual AIAA Aviation, Technology, Integration and Operations Conference*, Atlanta, GA, June 16-20.
  - Measured Response B – Controller Acceptability
    - Vu, K. L., Morales, G., Chiappe, D., Strybel, T. Z., Battiste, V., Shively, J., & Buker, T. J. (2013). Influence of UAS pilot communication and execution delay on controller's acceptability ratings of UAS-ATC interactions. *Proceedings of the 32nd Digital Avionics Systems Conference*, Syracuse, NY, October 6-10.

ATC Performance

Part Task 3: Impact of UAS Contingency Operations on ATC

- **Objective**: to examine the effects of various, currently-employed UAS contingency procedures on sector safety and efficiency, and ATC workload.
  - Four contingency procedures compared to no contingency
  - Two main categories of contingencies: lost link and critical systems failure

ID	Event	Contingency Behavior	Time to Execute
C1	Baseline	N/A	N/A
C2	Lost Link	Return to base	1 min
C3	Lost Link	Return to base	8 min
C4	Lost Link	Maintain pre-programmed course, return to mission altitude	1 min
C5	Drop in Oil Pressure	Land at emergency site	Immediate



Main results/conclusions:

- Contingency procedures had no significant effect on objective measures of sector safety or efficiency; none differed significantly from baseline (no contingency)
- No significant differences in self-reported workload or situation awareness of the ATC participants
- Participants preferred procedures that minimized deviations and/or provided them with sufficient time to manage nearby aircraft in preparation for pre-planned deviations
  - Highlights need for standard and predictable contingency procedures

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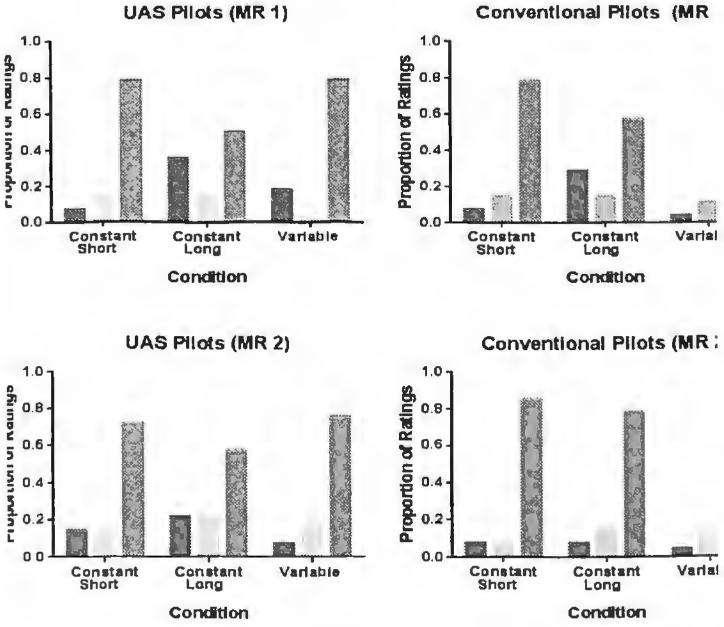
ATC Performance

Measured Response B: Effect of Pilot Communication and Execution Delay

- **Objective**: to determine how verbal response delays, execution delays, and delay predictability impact ATC acceptability ratings of UAS pilot responses.



Main results/conclusions:

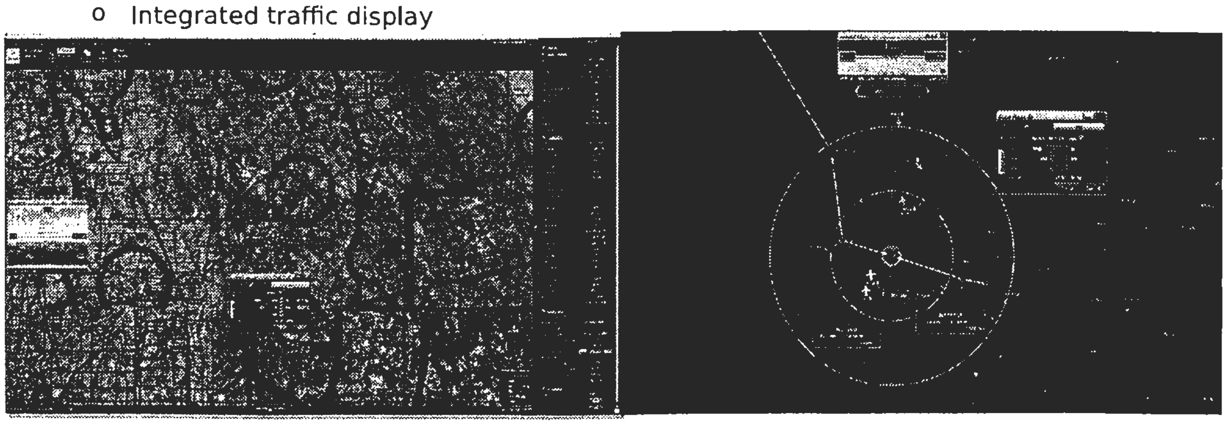
- ATC acceptability ratings were driven mainly by the verbal latencies.
  - Short UAS verbal latencies averaging 2.10s were mostly acceptable to ATC
  - Long UAS verbal latencies averaging 5.48s were not as acceptable
- Execution latencies and the predictability of the delays had less of an influence on ATC acceptability ratings
- Results provide a baseline

Objective I: GCS Guidelines Development

- Radio Technical Commission for Aeronautics (RTCA) Special Committee 228: Minimum Operational Performance Standards (MOPS) for Unmanned Aircraft System for Detect and Avoid (DAA) and Command and Control (C2)
- HSI is currently leading the Human-Machine Interface (HMI) requirements for the DAA and C2 working groups of the MOPS
- Potential HMI MOPS Requirements, Recommendations or Impacts will address:
  - Displays
    - minimum information
    - advanced decision aiding/pilot guidance
    - monitoring and control of C2 links
  - Self Separation and Collision Avoidance Alerting
  - Control interfaces
    - Levels of automation
      - Effect on pilot performance, C2 links
  - Visual (i.e., camera/out-the-window) information requirements by phase of flight
- Phase I MOPS due July 2016
- General GCS Requirements
  - Will include those requirements not covered within the DAA and C2 sections of the SC-228 MOPS
  - To be published as a NASA report

Objective II: Prototype Development

- The Vigilant Spirit Control Station (VSCS) will serve as the prototype GCS for the UAS Integration into the NAS Project
  - Robust, flexible interface
  - Multi-UAS control with VSCS has been tested in simulation and flight by AFRL
  - STANAG 4586 Compliant
- Current UAS in the NAS version includes:
  - Single UAS control
  - NAS-compatible database (low- and high- altitude charts with navigational aids/"fixes")
  - Integrated traffic display



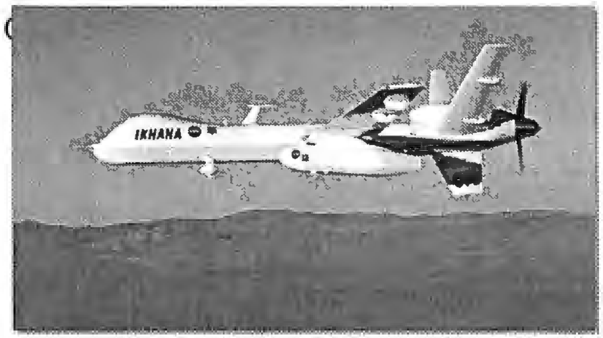
Vigilant Spirit Control Station (AFRL/RH). Distribution A: Approved for public release, distribution unlimited. 88ABW Cleared 3/18/2013 88ABW-2013-1303

Summary of HSI Activities

- Information Requirements:
  - Single searchable database combining three separate analyses:
    - Phase of Flight
    - Functional (e.g., aviate/control, manage, avoid, etc.)
    - Evaluation of existing Federal Air Regulations (FARs)
- Simulation Experiments:
  - Pilot Performance
    - Part Task Simulation 1– Baseline Compliance
    - Measured Response A – Response to ATC Clearances
    - Full Mission Simulation 1 – Command and Control Interfaces
  - ATC Performance
    - Part Task Simulation 3 – Contingency Management
    - Measured Response B – Pilot Communication and Execution Delay
- Objective I: GCS Guidelines
- Objective II: Prototype Development

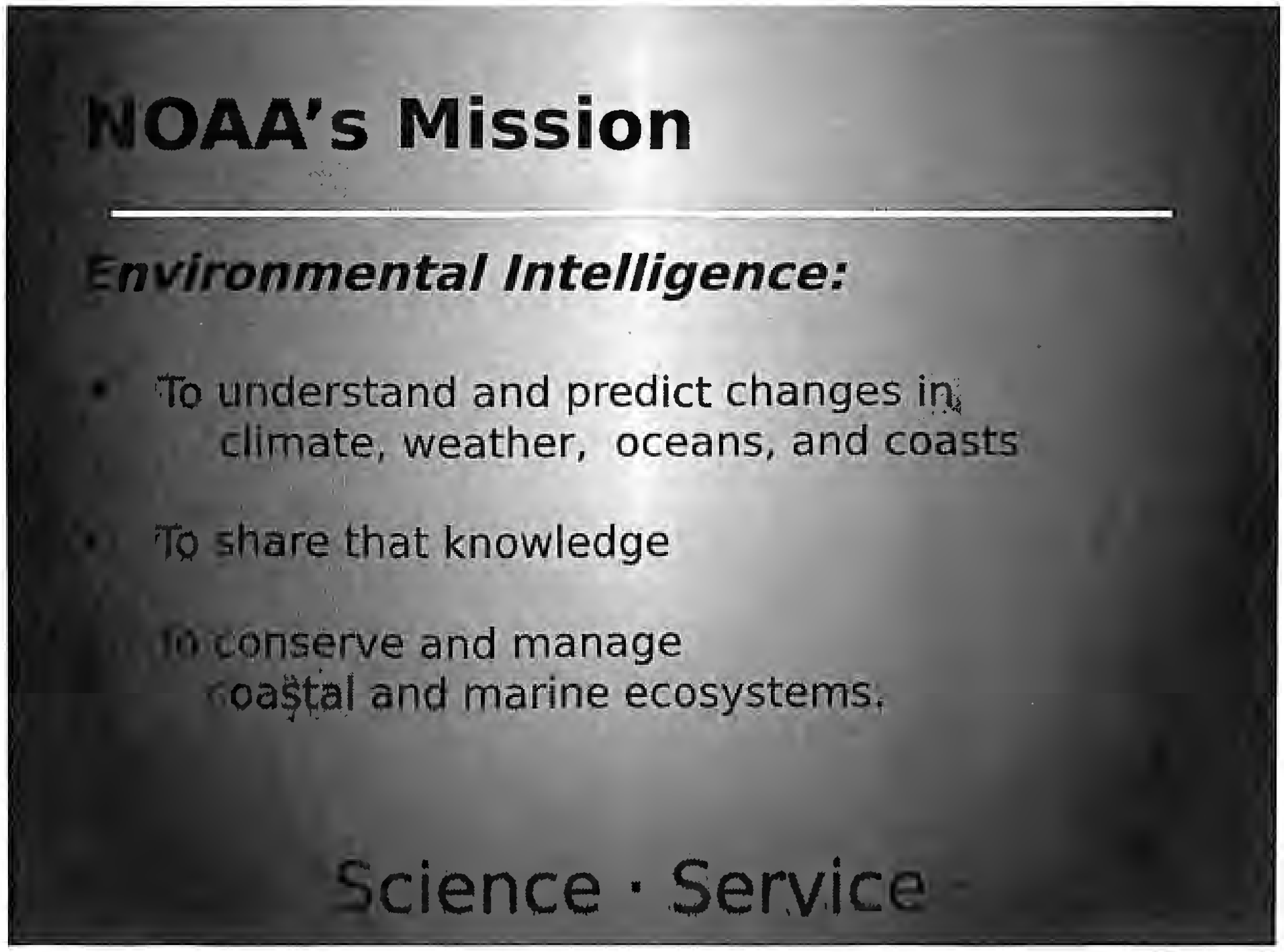
Phase 2 Activities

- Simulation experiments to focus on DAA requirements:
  - Part Task Simulation 4:
    - Minimum display requirements
    - Advanced information and pilot guidance
    - Stand alone versus integrated displays
  - Part Task Simulation 5:
    - Evaluation of additional DAA displays
  - Full Mission Simulation 2:
    - Evaluation of boundary between self-separation, collision avoidance and autonomous collision avoidance
- Flight Tests to validate prototype displays in operationally relevant environment
  - ACAS Xu Flight Test NOV 2014
  - Flight Test 3 JUL 2015
  - Flight Test 4 APR 2016



EXPLORING ADVANCED CONCEPTS OF OPERATIONS FOR UNMANNED MARITIME VEHICLES

Capt. Craig McLean, NOAA (Ret.)
Assistant Administrator (Acting)
Office of Oceanic & Atmospheric Research
National Oceanic and Atmospheric Administration | NOAA
May 13, 2014

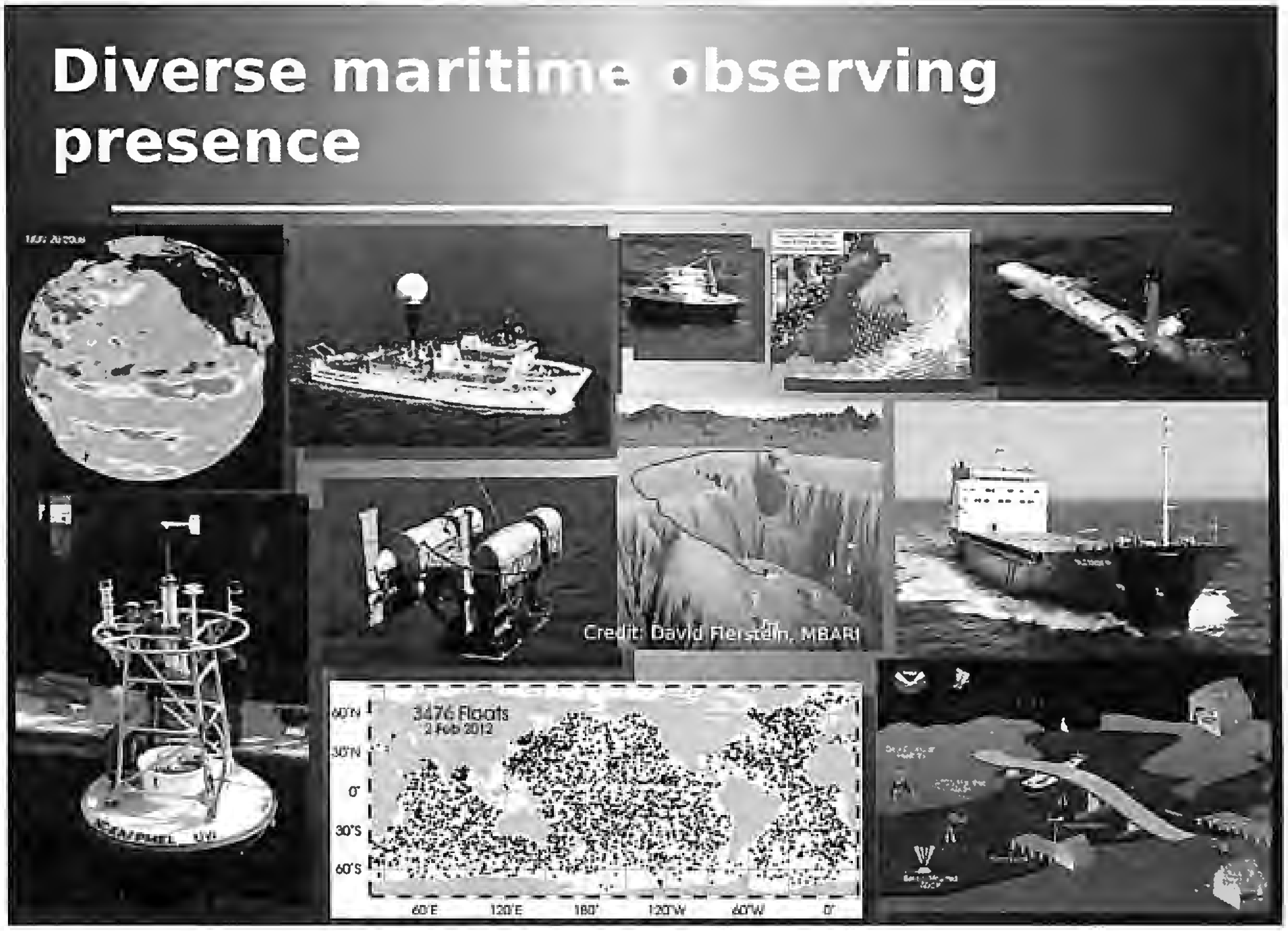


NOAA's Mission

Environmental Intelligence:

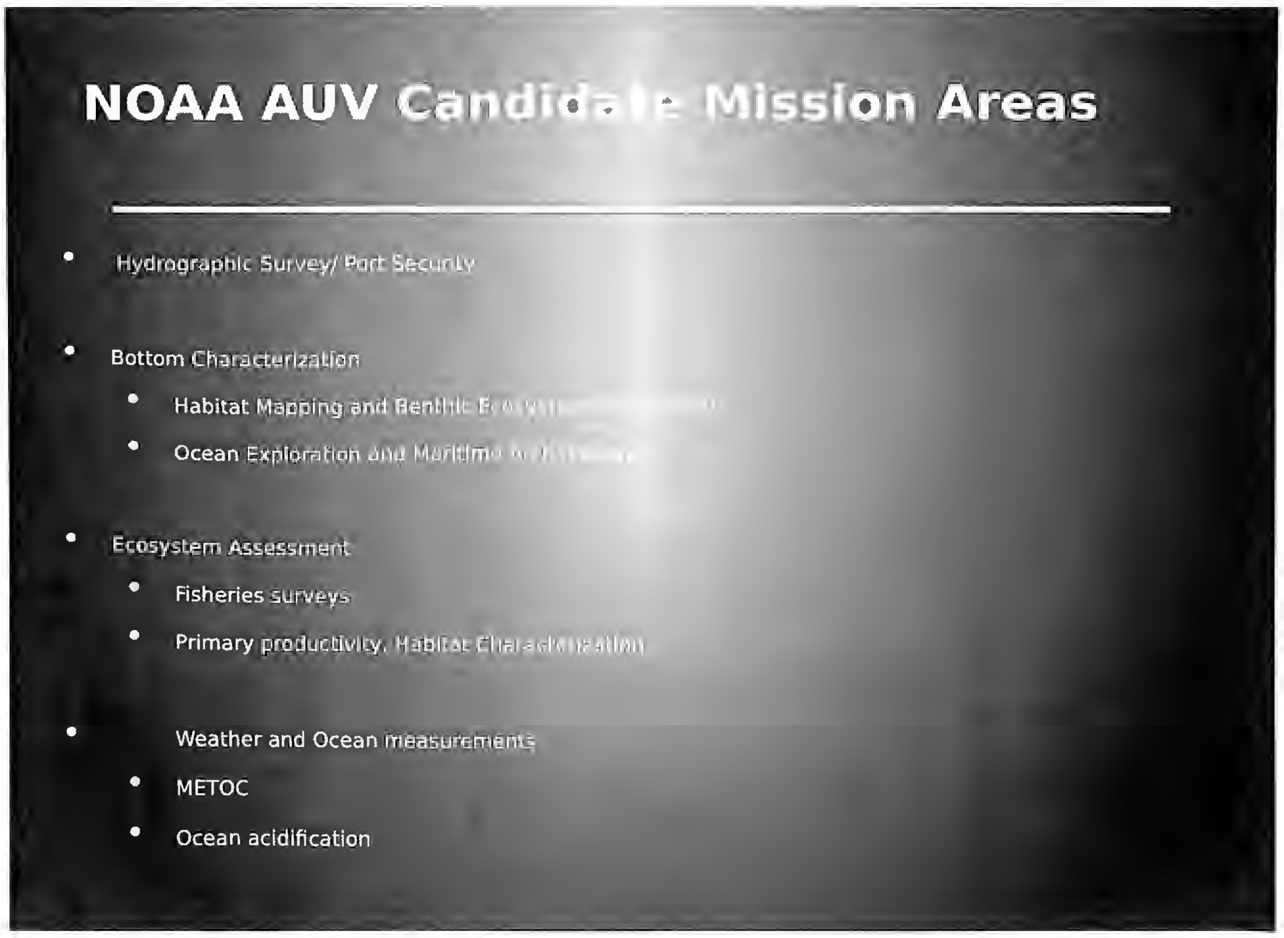
- To understand and predict changes in climate, weather, oceans, and coasts
- To share that knowledge
- To conserve and manage coastal and marine ecosystems.

Science · Service



Diverse maritime observing presence

Credit: David Fierstein, MBARI



NOAA AUV Candidate Mission Areas

- Hydrographic Survey/ Port Security
- Bottom Characterization
    - Habitat Mapping and Benthic Ecosystem [illegible]
    - Ocean Exploration and Maritime [illegible]
- Ecosystem Assessment
    - Fisheries surveys
    - Primary productivity, Habitat Characterization
- Weather and Ocean measurements
    - METOC
    - Ocean acidification

Unmanned Systems for Arctic Observations

NOAA's Arctic Action Plan released [illegible] 2014. Strategic goals include:

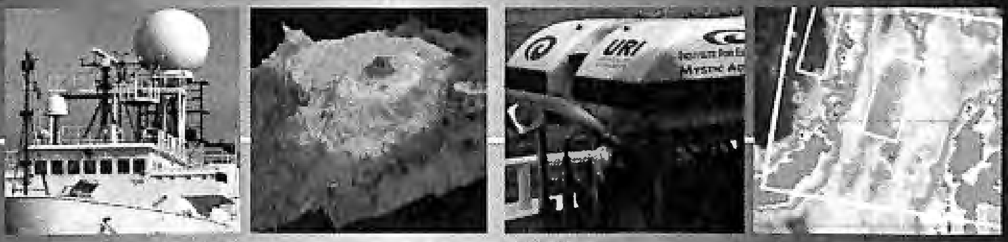
- Forecast sea ice
- Improve weather and water forecasts and warnings
- Understand and detect Arctic climate and ecosystem changes
- Improve stewardship and management of Arctic ocean and coastal resources
- Advance resilient and healthy Arctic communities and economies
- Enhance international and national partnerships

Where Are We Headed?

Considerations

Present ConOps Not Sustainable to Meet Mission.

- ? Who Develops the Solution?
- ? Who Already Has?
- ? Need to Own the Solution?
- ? The Big Buy.



Questions?