



small Unmanned Aircraft System (sUAS) Human Systems Integration (HSI)

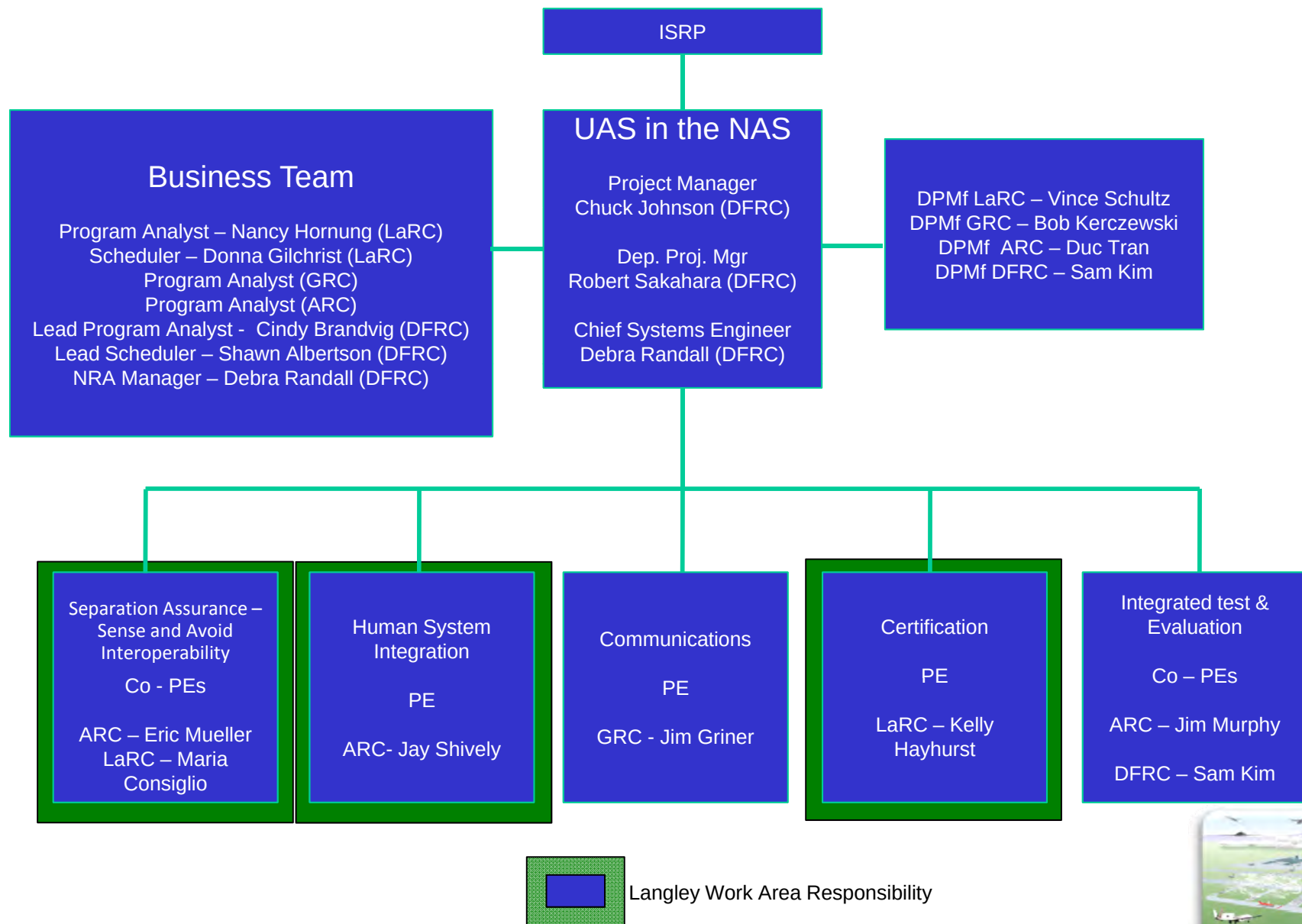
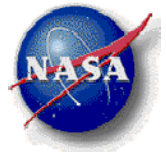
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UAS in the NAS Project Team



UAS in the NAS HSI Objectives



Objective 1:

- Develop a research test-bed and database to provide data/proof of concept for Ground Control Station (GCS) NAS operations

Objective 2:

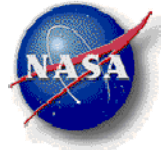
- Coordinate with standards organizations to develop human factors guidelines for GCS operation in the NAS



- Interest in UAS routine access:
 - (1) Federal government – DHS, NOAA, Commerce, Interior, FBI, DOT
 - (2) Military
 - (3) Local governments – police, fire, port authority
 - (4) Commercial – utilities, news agencies, private security, photographers, hobbyists



LaRC = sUAS HSI



- **LaRC is focusing on sUAS**
 - ≤ 55 lbs
 - Highly portable
 - Differing levels of autonomy

sUAS Drivers/Benefits:

- **Cost**
 - Manufacture
 - Operational
- **Miniaturization**
- **Significant interest from civil and private operators**
 - NASA's UAS in the NAS project involves both
- **FAA re-authorization bill →**

Army Going Big on Small Drones

Aol Defense (Aug 17, 2011)

"... have gotten the most bang for their buck from the smaller-class of unmanned drones ..."

LM Introduces Ruggedized Extreme Endurance UAS

The Salt Lake Tribune (Aug 16, 2011)

"Missions requiring real time eyes-on a situation for extended periods of time, like border patrol, pipeline surveillance and special operations can now be conducted by a small UAS versus a larger, more costly system."

Bridging the Observations Gap Between Earth and Space

NOAA

"Successfully tested the ability of a small UAS to measure evaporation from the ocean surface along the California coast"

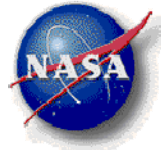
Editor's Note: UAS Integration

Avionics Magazine (May 1, 2011)

"FAA in 2008 established an Aviation Rulemaking Committee to recommend how to proceed on regulating small UAS, where the greatest market growth is projected."



FAA Reauthorization Bill – sUAS Slated First



- In 90 days, first responders will be able to fly *25 lbs drones* within the *line of sight* of the operator, *less than 400 feet* above the ground, during daylight conditions, inside *Class G airspace* and more than five miles from any airport or other location with aviation activities
- In 6 months, designate permanent areas in the Arctic where sUAS may operate 24 hours per day *beyond line of sight* to at *least 2,000 feet* in altitude
- In 18 months, civil operation of sUAS in the NAS
 - No mention of airspace class limitations or line-of-sight limitations



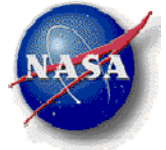
Areas of Focus – sUAS Difference



- **Pilot issues**
 - Loss of senses – Differing levels especially for line-of-site ops
 - Crew handovers – Line-of-site may be non-collocated pilots
- **Ground station issues**
 - Lack of application of 70+ years manned cockpit experience (but it's not a cockpit) – GCS may be an RC controller
- **Airspace issues – Potentially significant issues**
 - Aircraft Performance – Wide range of speeds and maneuverability
 - Mixed Equipment – Size limits
 - Sense and Avoid – Vehicle footprint and equipment limits
 - sUAS that may need to interact with ATC but may have limited equipage due to vehicle size



Specific NASA sUAS Challenges



- **Airspace**

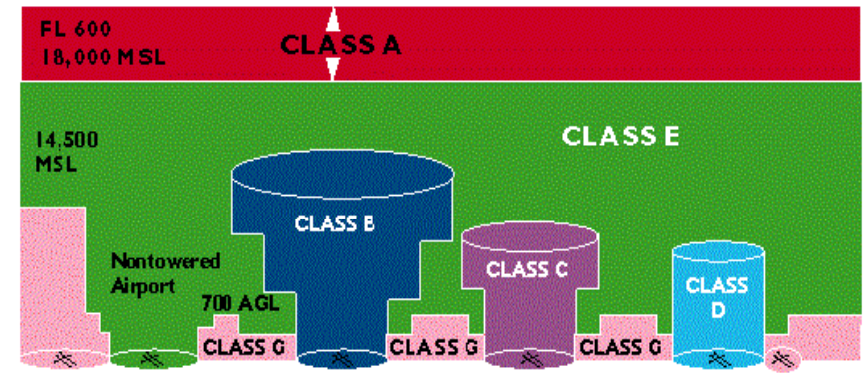
- sUAS may have limited equipage due to vehicle size

- Typically in Class G Airspace

May need to operate in Class D or E Airspace

May need to transit through Class B – C Airspace

Requested by first responders and private operators



- **Portable GCS**

- Cross-control problem for line-of-sight UAS

- Point-and-click interface

- Menu driven

- On-the-loop control

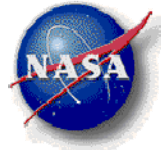


not flown but **COMMANDED**

- RC controller



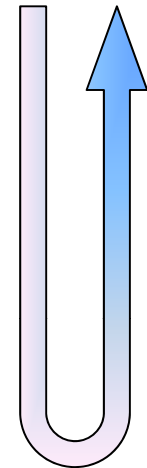
Technical Approach



Objective 1: Proof of concept GCS

- Develop candidate displays (visual, auditory, etc.)
- Integrate with an existing GCS
- Test
 - Part-task simulation
 - Integrate with ATC
 - Flight test

Revise
&
Repeat



Objective 2: Coordinate with standards organizations

- Coordinate with: FAA
SC-203
- Possibility with: ASTM-F38



GCS Information Requirements

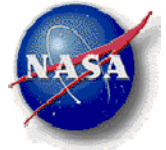


- Literature search
 - AIM, Air Traffic Operations manual, FARs, etc.
 - Ames information requirements categorized by phase of flight
 - Contract with Research Integrations Inc. to categorize information requirements by FARs
 - LaRC information requirements categorized by aviate, navigate, communicate, manage systems/payload
- Survey & phone interviews
 - Elicit GCS information requirements via survey (Ames & LaRC) and phone interviews (LaRC) from:
 - (1) UAS and sUAS pilots
 - (2) Manned-aircraft pilots
 - (3) Air traffic controllers

Concerns regarding sUAS



LOS Algorithm



Estimate visibility of a small UAS as a function of the following variables:

- Orientation relative to and distance from observer:

Calculated by perspective projection

- Sun glare

- Color Contrast – UAS against background sky

- Preetham model for Sky Light Color

(Preetham et.al. A Practical Analytic Model for Daylight, SIGGRAPH 99, 26 91-100 (1999))

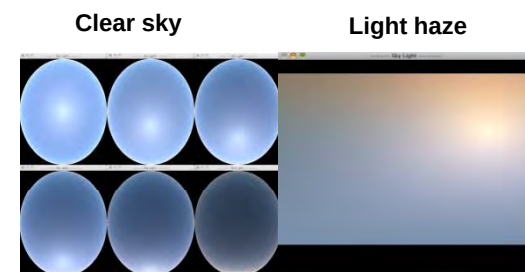
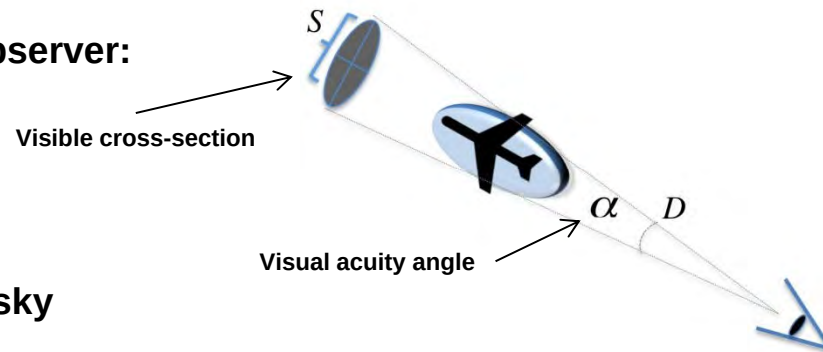
- Score contrast (white/black) = 21 , (white/white) = 1.0

- Atmosphere and Weather between observer and craft

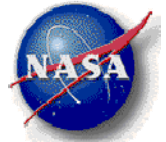
$C = C_0 \exp(-\sigma r)$; where C/C_0 is a rescaled color contrast value
 σ is an extinction coefficient different for
clear sky, rain, haze, fog, etc...

- Obstruction of observer's view of aircraft, by either buildings or topology

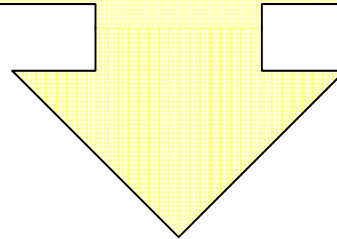
- Next step is displaying this information to the sUAS pilot



LaRC Human-in-the-Loop (HITL) Experiments



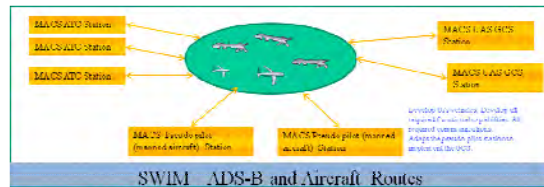
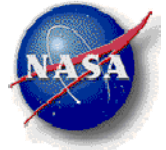
- **HITL01 = GCS Checkout and nominal line-of-sight operations**
(FY12Q4)
- **HITL02 = Nominal operations with beyond-line-of-sight**
(FY14Q3)
- **HITL03 = Non-normal operations (e.g., lost link)**
(FY15Q3)



- **Results will feed into:**
 - (1) Flight Tests
 - (2) Information requirements
 - (3) CONOPS/Guidelines



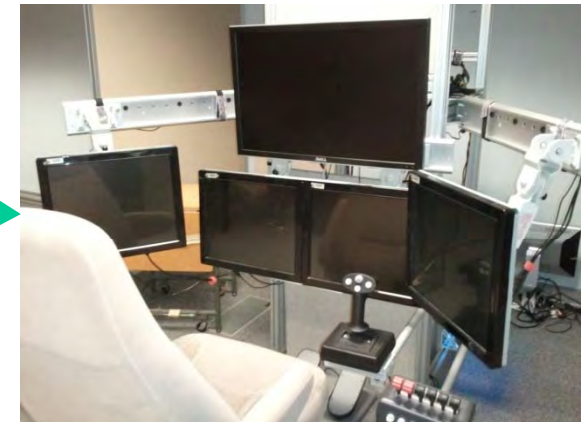
sUAS GCS Simulation Platform



SA Sim Platform

MACS
(Multi Aircraft
Control System)
Designated by project
(for sUAS,
communications protocol)

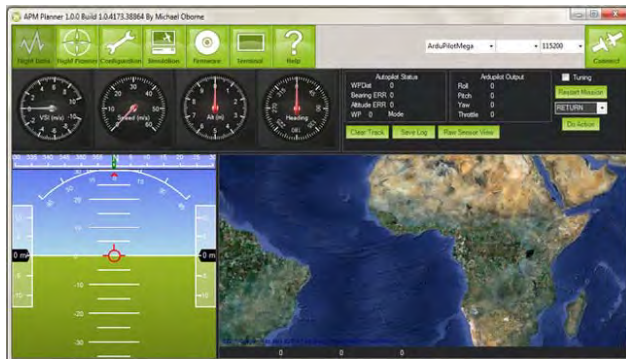
Other Sims



IDEAS Lab

GCS

Developing basic line-of-sight GCS
Attitude, position, system status, communications



AirSTAR



- 5.5 % geometrically & dynamically scaled model
- 49.6 lbs (54 lbs full) → sUAS
- Open-source simulation framework



CONOPS/Guidelines



For sUAS, CONOPS/Guidelines will include:

- **Typical sUAS vehicle characteristics**
- **Airspace requirements in both uncontrolled and positively controlled airspace effects on GCS**
- **GCS portability issues**
- **Line-of-sight and beyond-visual-range operations effects on GCS**
- **Manual flight control to highly-automated flight**



Questions?

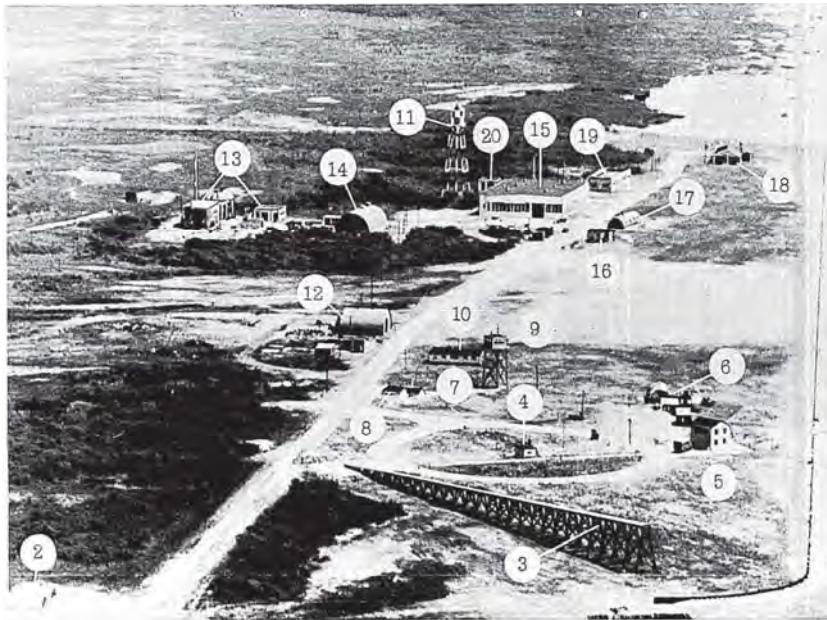
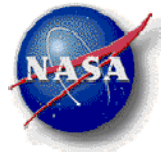


Figure 42.- Pilotless Aircraft Research Station, Wallops Island, June 2, 1947.

Pilotless Aircraft Research Station, Wallops June 2, 1947

U.S. Says Drone, Cargo Plane Collide Over Afghanistan

By NATHAN HODGE

An Air Force cargo plane collided with a drone in Afghanistan, a potentially serious mishap that could give ammunition to critics wary of allowing pilotless aircraft to operate in civilian airspace.

Air Force Capt. Justin Brockhoff, a spokesman for the military in Afghanistan, confirmed that a C-130 cargo plane made an emergency landing Monday at a base in eastern Afghanistan after colliding with an RQ-7 Shadow, an unmanned aerial vehicle that is usually operated by the Army and the Marine Corps.

"The C-130 received damage during the incident and the aircrew was unharmed," Capt. Brockhoff said.

The Shadow, usually employed by a brigade, is about 12 feet long with a 20-foot wingspan. Launched by a catapult, it can stay aloft for more than five hours and has a range of about 30 miles. An Army official said controllers on the ground apparently didn't lose contact with the

Drones' potential civilian applications are hindered by their lack of collision-avoidance systems.

Shadow until it collided with the C-130. "We were in complete control up until the collision," the official said.

Over the past decade, the U.S. military has built a large fleet of remotely piloted aircraft. Even so, collisions between manned aircraft and pilotless spy planes

WSJ, Wednesday, August 17, 2011
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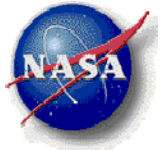
Separation Assurance for sUAS



- UAS in the NAS is NOT looking at separation assurance issues for sUAS
- For sUAS trajectory planning in non-positively controlled airspace
 - How much warning does the sUAS pilot need in order to avoid other traffic depending on the flight characteristics of his sUAS
 - When does the sUAS have to maneuver independently in order to avoid a collision
 - What should the maneuver be in order to minimize confusion on the part of the sUAS pilot, ATC, and to affect the flight plan the least



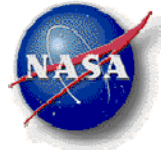
Lost Link



- **Lost link is a concern for both the sUAS pilot and ATC**
- **For sUAS, this is especially true because sUAS typically not flown in positively controlled airspace**
- **Intermittent lost link**
 - How long a link must be out before initiating a lost-link procedure in order to maintain safety while minimizing lost-link false alarms
 - Condition causing lost link
 - Can lost link be avoided by modifying the flight plan



Possible Future Research / Other Concerns



Beyond Visual Range

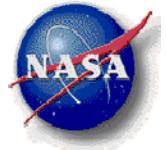
- Although the FAA has initially indicated sUAS will be LOS →
 - (1) FAA re-authorization bill said “In 6 months, ... sUAS may operate ... *beyond line of sight* to at least 2,000 feet in altitude
 - (2) sUAS are already operating BVR → Scaneagle
- Transitions from manual line-of-sight flight to a more autonomous beyond-visual-range-flight

Trajectory Planning

- Computing return to base trajectories and updating flight plan to pilot (and ATC)
- Autonomous flight planning depending on the mission (and updating the pilot and ATC)



Possible Future Research / Other Concerns



System Failures

- Controlling failures and subsequently updating trajectories based on those failures

Handoffs

- Maintain stable flight, situation awareness, etc. during handoffs between pilots
 - Collocated pilots
 - Remotely located pilots

