Overview of Requirements for Semi-Autonomous Flight in Miniature UAVs (MAV)

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www.crasar.org

Outline

- Introduction
- Operations conducted and data collected
- Requirements and Recommendations
- Summary

Core findings about Requirements:

- Minimum useful standoff distance is 2-5m
- Omni-directional sensor capabilities needed for obstacle avoidance
- GPS waypoint nav is unnecessary
- Requires 3 operators to 1 UAV

iSSRt & Unmanned Systems

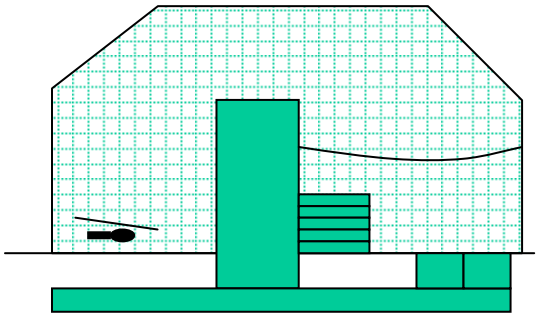
Information Technology for Safety, Security, & Rescue
~3M in research, faculty from all disciplines

SSR-RC
SAFETY*SECURITY*RESCUE
RESEARCH CENTER

NSF industry/university cooperative research center with Minnesota, CMU, UPenn, and industry partners (including iSensys)

Center for Robot-Assisted Search and Rescue

Field work



National Testbed:

Cooperative Agreement with Edgewood Chemical Biological Center

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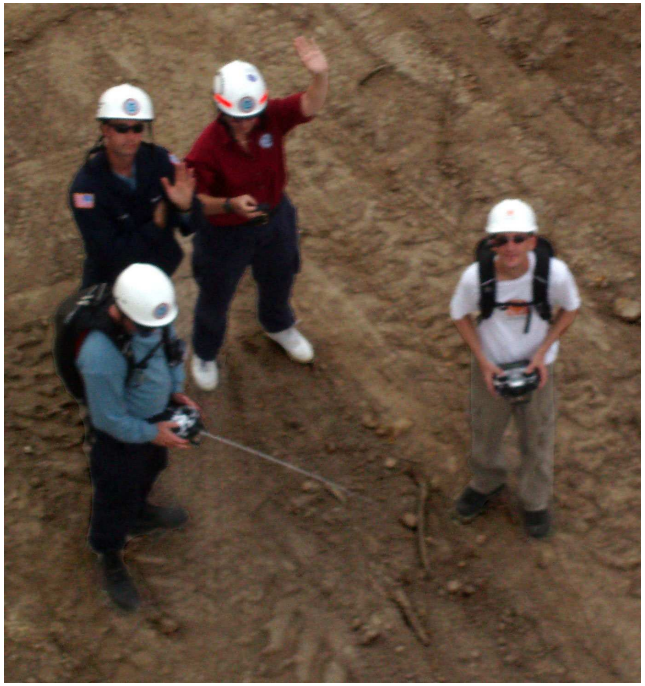
Requirements Based on UAV Field Experience

- Mar 2005, Simulated bus hijacking, Tampa Police Dept., Tampa Fire Department, Hillsborough County Sheriff's Office
- July 2005 “Camp Hurricane” technology exercise at Tampa Fire Training Academy
- **Aug. 31-Sept 1, 2005 Hurricane Katrina Hancock County (Mississippi) Florida State Emergency Response Team**
- **Oct. 26, 2005 Hurricane Wilma, structural inspection of MIYC**
- **Nov. 29-Dec. 5, 2005 Hurricane Katrina, National Science Foundation project to archive structural data**



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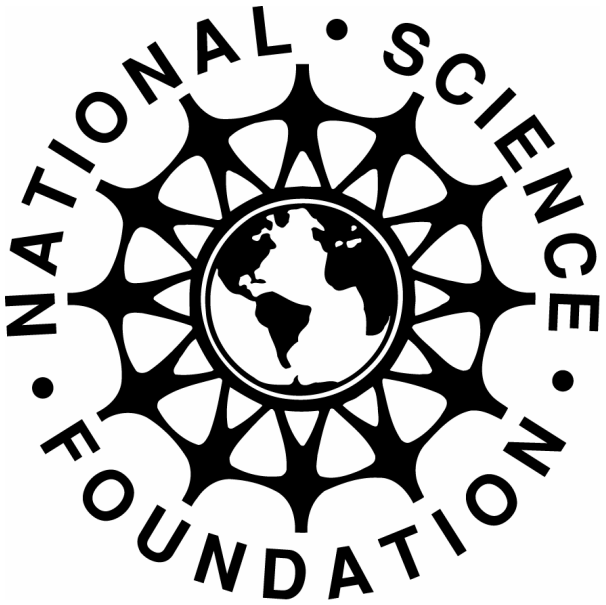
“Return to Katrina”

- NSF Small Grant for Exploratory Research : “Hurricane Katrina- Documenting Damage to Multi-Story Commercial Structures along the Gulf Coast using Rotary-Wing Unmanned Aerial Vehicles”
- Primary Mission:
  - Photo-document from previously impossible viewpoints
- Secondary Mission:
  - Refine payloads and procedures for survey work with UAVs



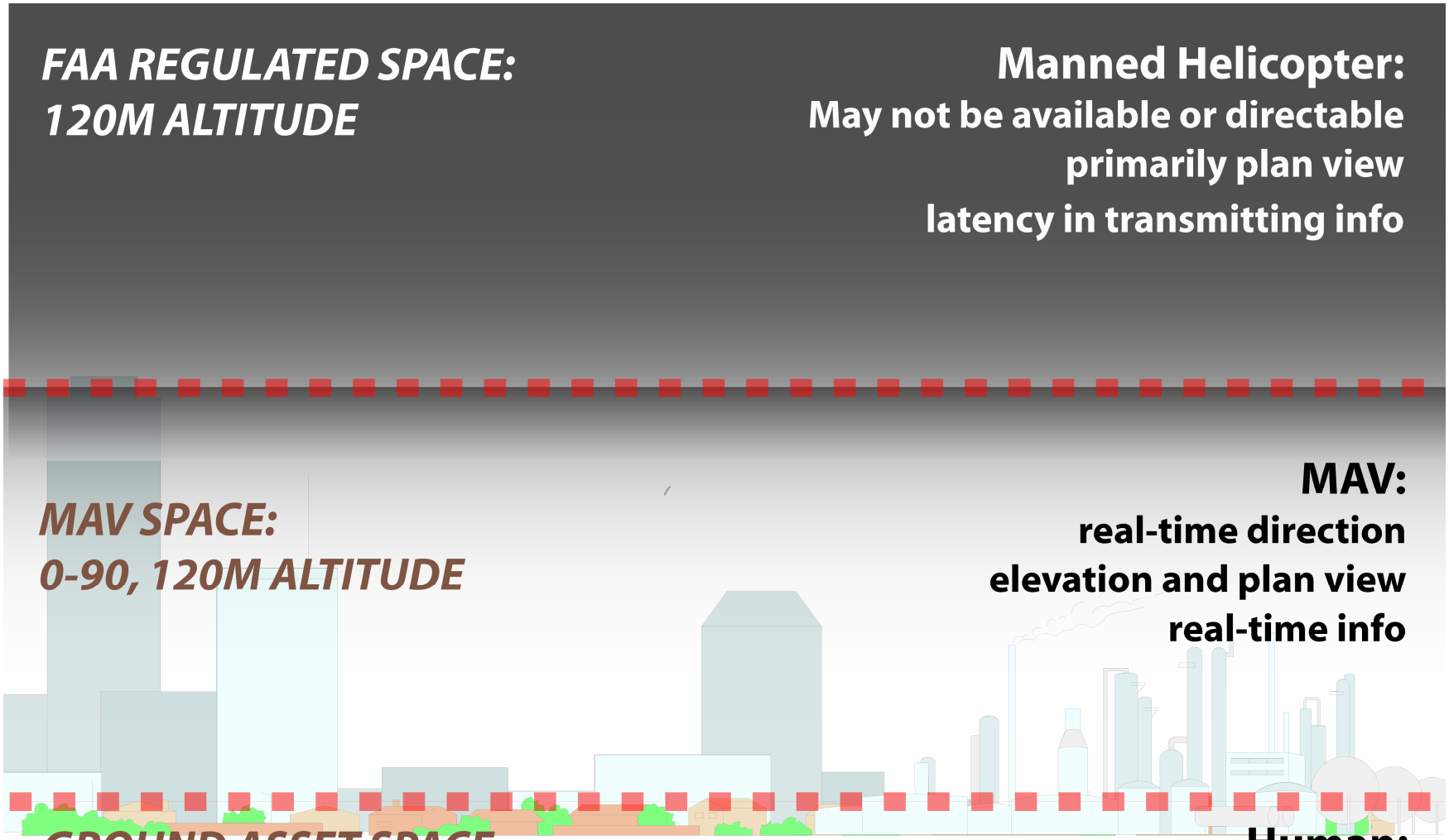
Overview of NSF Project

Initial Understanding of Structural Inspection

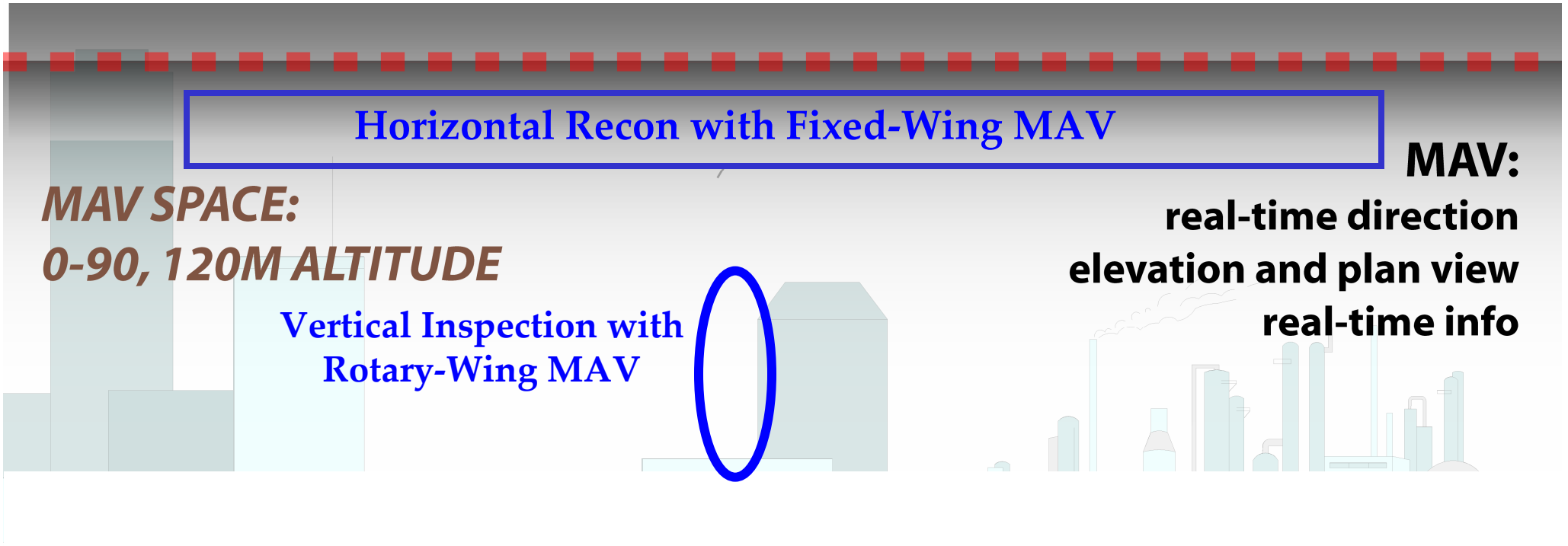
- Work Domain
  - Rescue phase: must work with responders
  - Recovery phase: permission of owner, insurance agency

- Key Tasks
  - Plan and elevation views, labeled consistently with search, structural engineering practice
  - Wide and zoom shots of damage
  - Image reachback to remote experts

MAV Airspace and Advantages

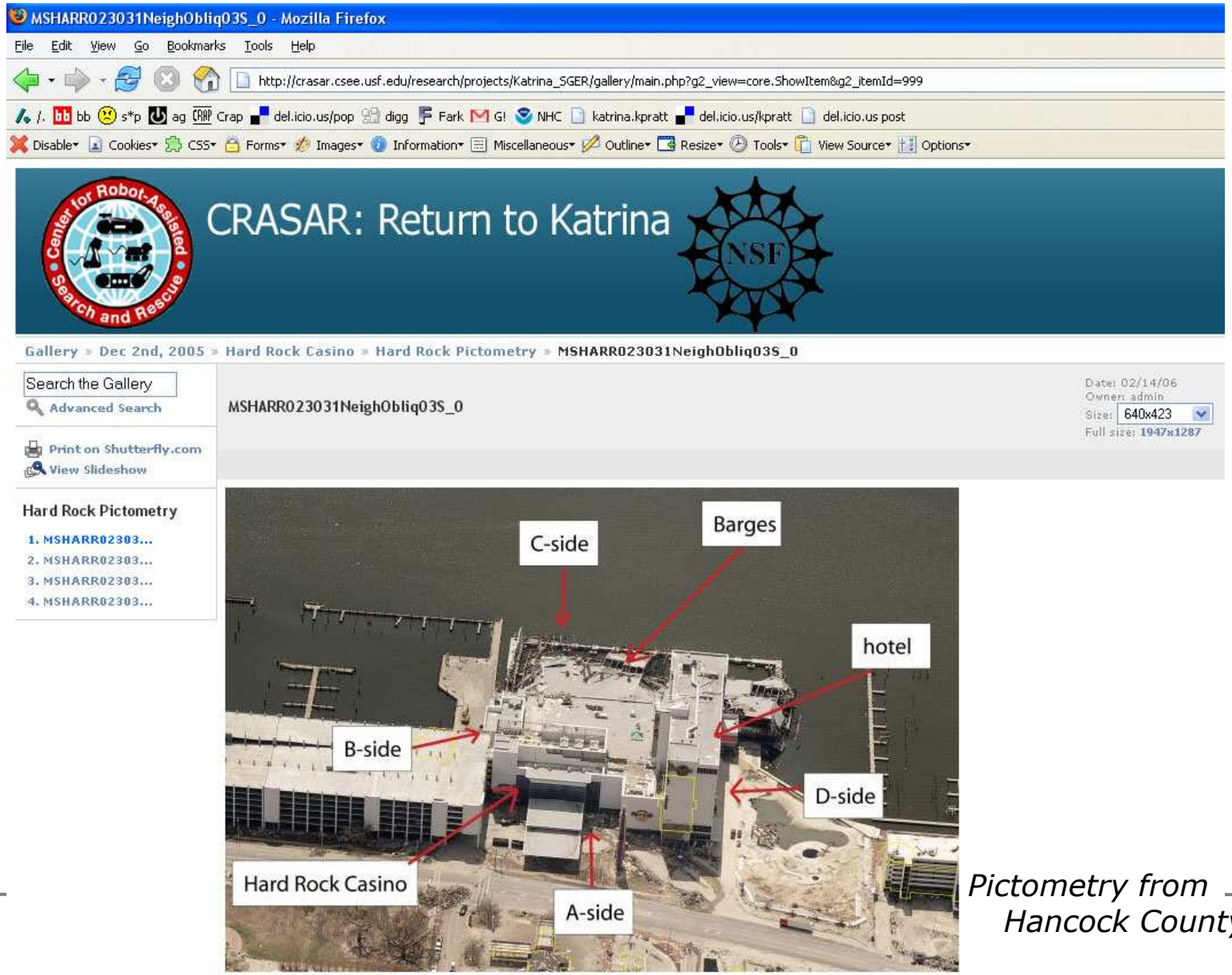


Fixed (Recon) vs. Rotary (Inspection)



Expected Data for Experts

http://www.crasar.org/research/projects/Katrina_SGER/



Pictometry from Hancock County EOC

Data Collected and Relevance to UAV Autonomy

- Introduction
- **Operations conducted and data collected**
- Requirements and Recommendations
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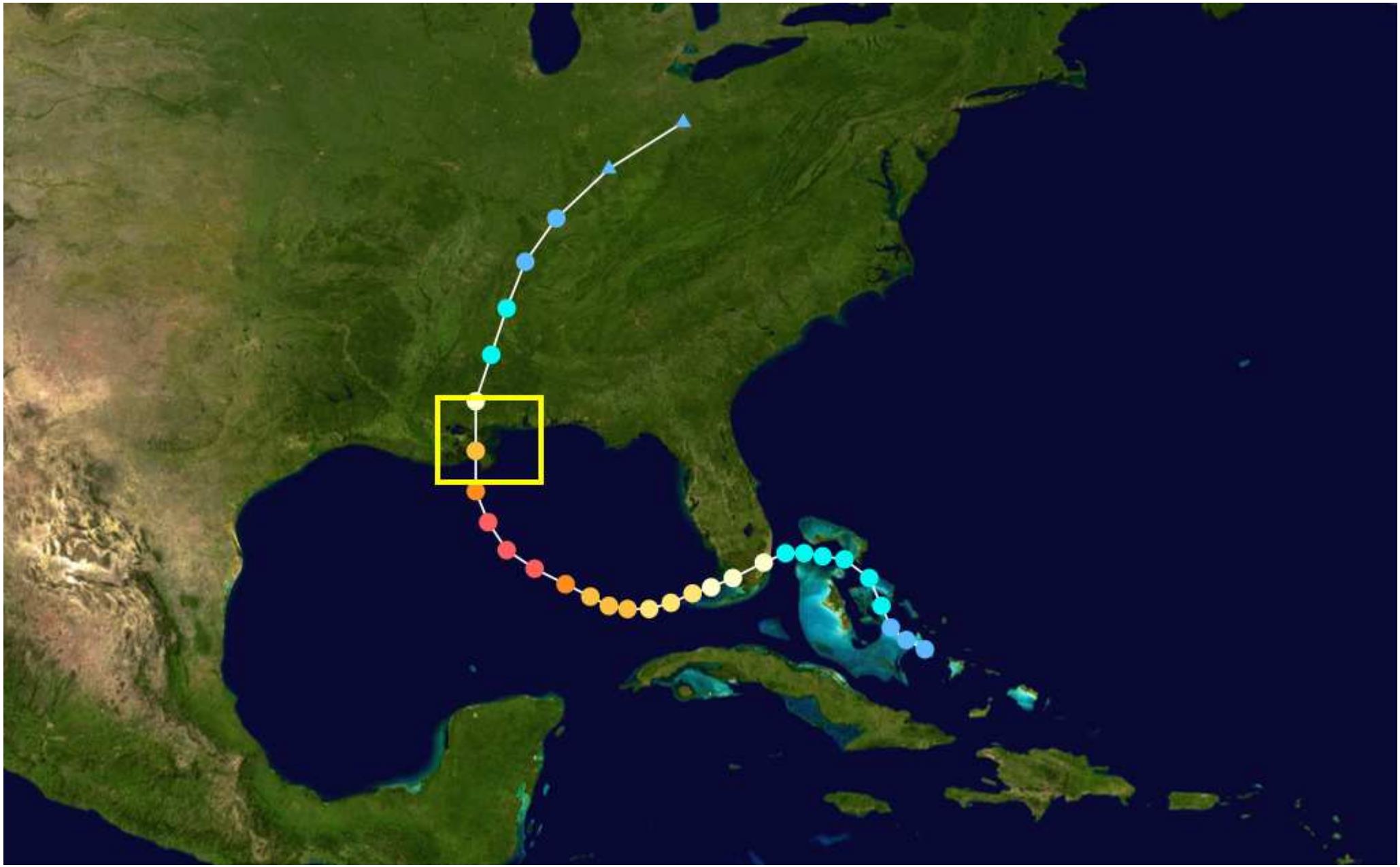
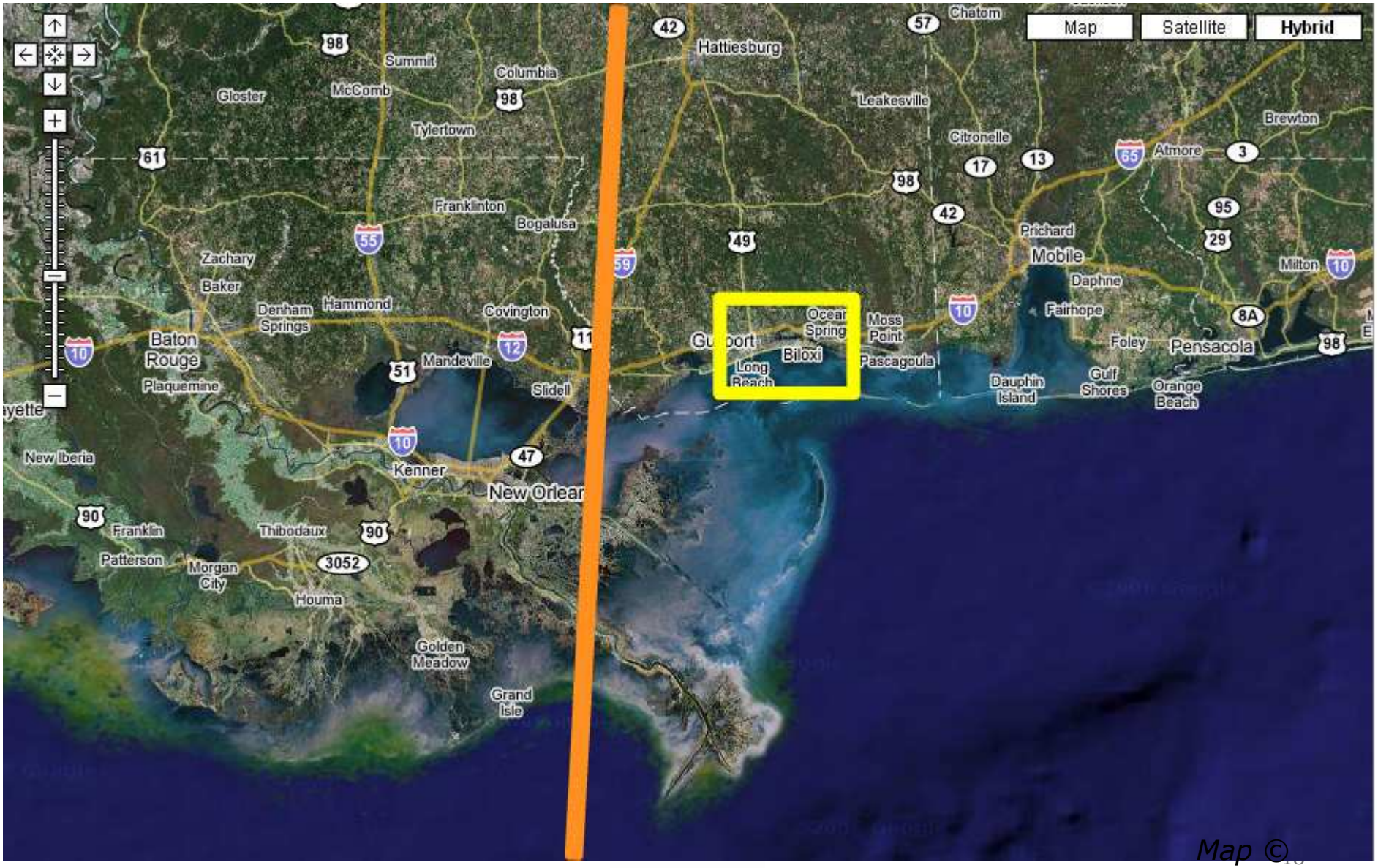
Katrina Storm Track



Hurricane Katrina stormtrack public domain from Wikipedia.com

Mississippi Coast

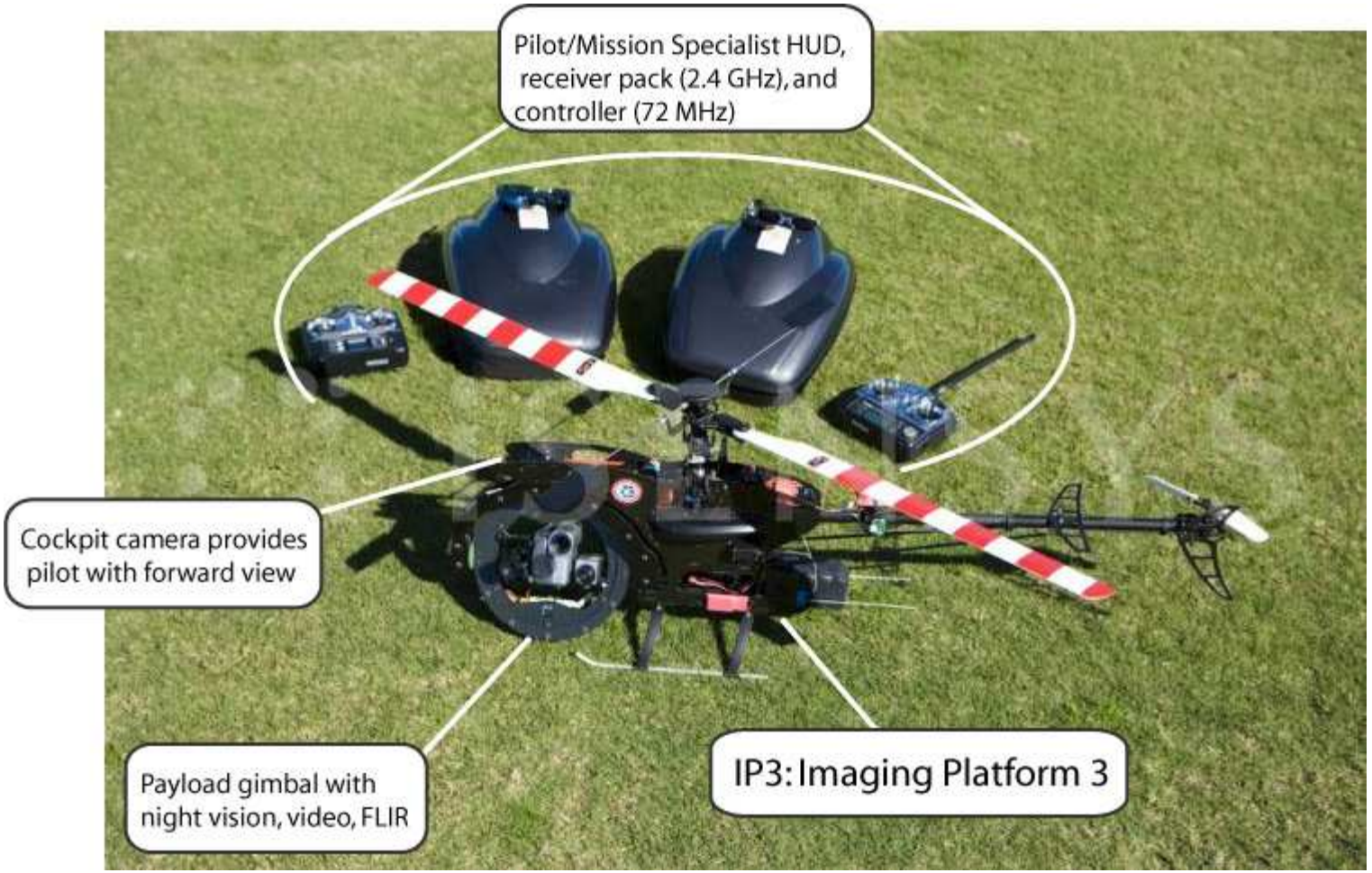


Map © Google 2006

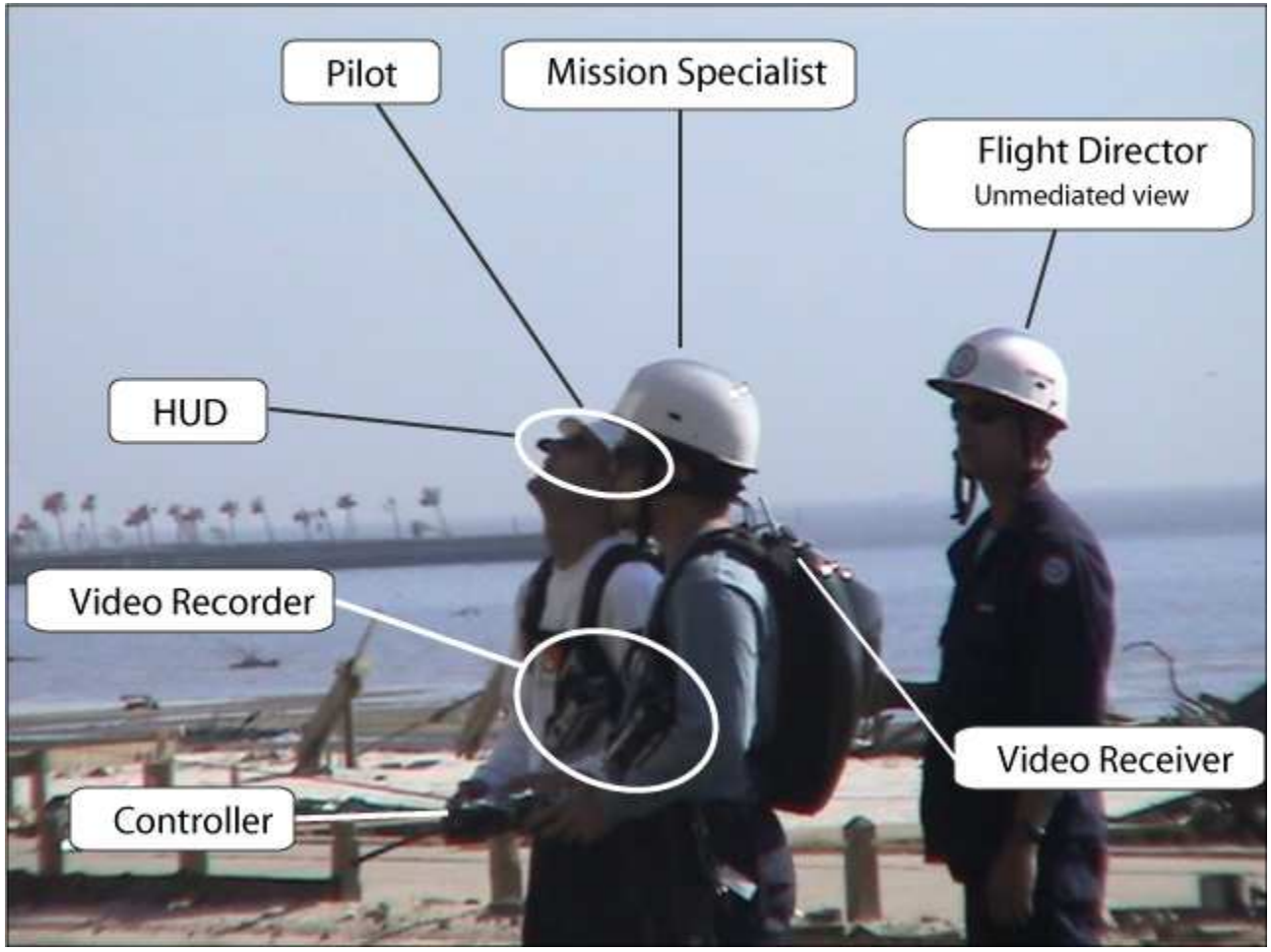
Six Structures Documented

Map © Google 2006

Equipment:
IP3 with Support Equipment



User Interfaces



Data for Structural Engineers

- Elevation and plan views
- High-res photographs, not video
- Location

Data for UAV Requirements

For each flight:

- **Flight team debriefings**
- **Video (used to support/amend team statements)**
- Vehicle telemetry
- Average and Max wind speed (1.5m and 7m)
- Other weather data
- Time and date of flight
- Flight duration
- Flight team voice recordings

3:1 Human to Robot ratio

3 Roles: Mediated Processes

HUD View from cockpit cam

Area of damage targeted by Flight Director

HUD View from payload camera at targeted area, looking down

Mission Specialist

Completely mediated

Pilot's eye view

Pilot

Mediated on-demand

Flight Director's eye view

Flight Director

Un-mediated

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Simulated viewpoints taken from Katrina data

Procedures for Flight

For each Flight

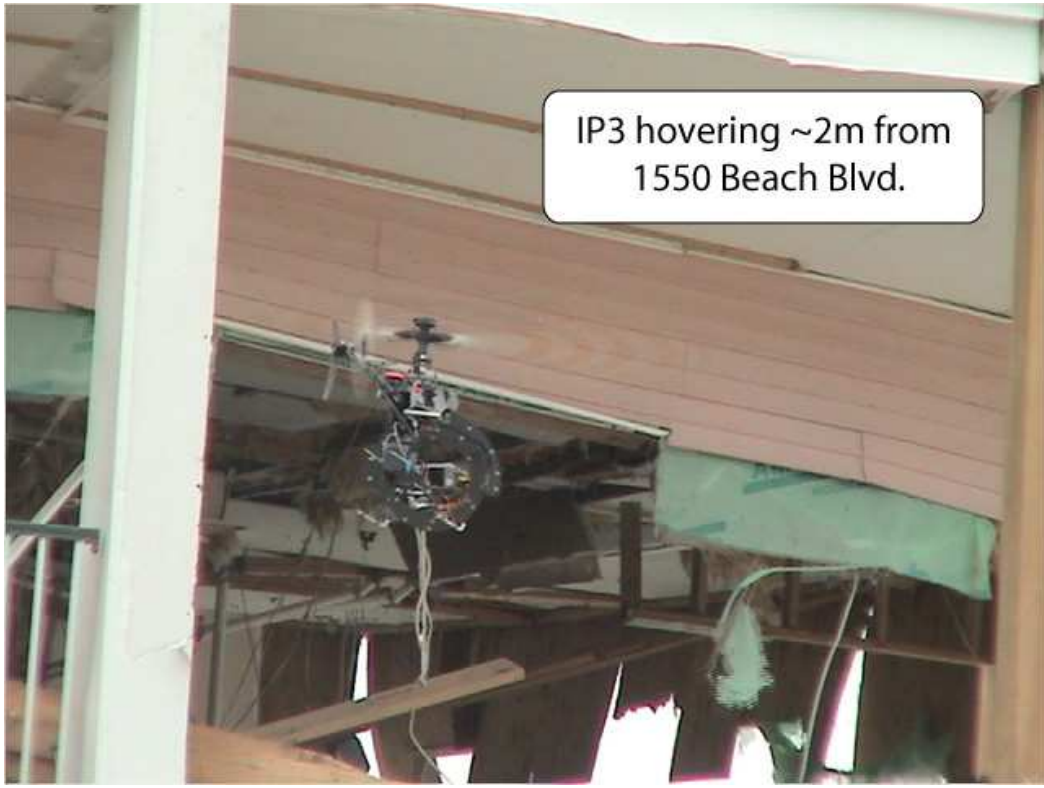
1. Check in with site representative
2. Safety review of site
   - Team access hazards
   - Safe zones
   - Platform hazards
3. Establish targets and mission sequence
4. Record pre-flight measurements
5. UAV and equipment preflight
6. Conduct mission
7. Record post-flight measurements
8. Notes

Daily

- Team debrief
- Reachback
- Archiving
- CWA Analysis

Short Hops and 2-5m Standoff

- Safety requires Line of Sight
- Surveying multiple sides of a building dictates multiple, shorter flights
- Structural survey needs close-up images, but 2-5m is plenty



Pictometry courtesy of Hancock County EOC

Team Members Need Structural Experience

Frequent In-flight Redirection

Unreliable Wireless Comms

- Consumer grade wireless comms systems are susceptible to interference and range
- Twisted and exposed metal at multiple sites severely degraded system performance

President Casino Barge

Requirements and Recommendations

- Introduction
- Operations conducted and data collected
- **Requirements and Recommendations**
- Summary

What is Needed?

- Work domain
  - Rescue phase: must work with responders
  - Recovery phase: permission of owner, insurance agency
- Key tasks
  - Plan and elevation views labeled consistent with search, construction practice
  - Wide and zoom still shots of damage
  - Image reachback to remote experts
- Strategies used to accomplish those tasks
  - 2-5 meter standoff distance from structure
  - Short hops of 5-8 minutes
  - Re-direction in air, not strict flight plan
  - high res photos for experts, video for team but perhaps not for experts
- Socio-organizational culture
  - 3 person field team, plus facilitator for reachback
- Worker competencies
  - Pilot, Mission Specialist, Flight Director
  - Structural field assessment experience

Other UAV Relevant Findings

- GPS wasn't used
  - GPS not always available
  - Flights shorter than time to enter
- Unpredictable "bubbles" or nodes of stable air near structures
  - Less stress on pilots, airframe
- Structural experts primarily concerned with details of damage

Requirements for Incremental Autonomy

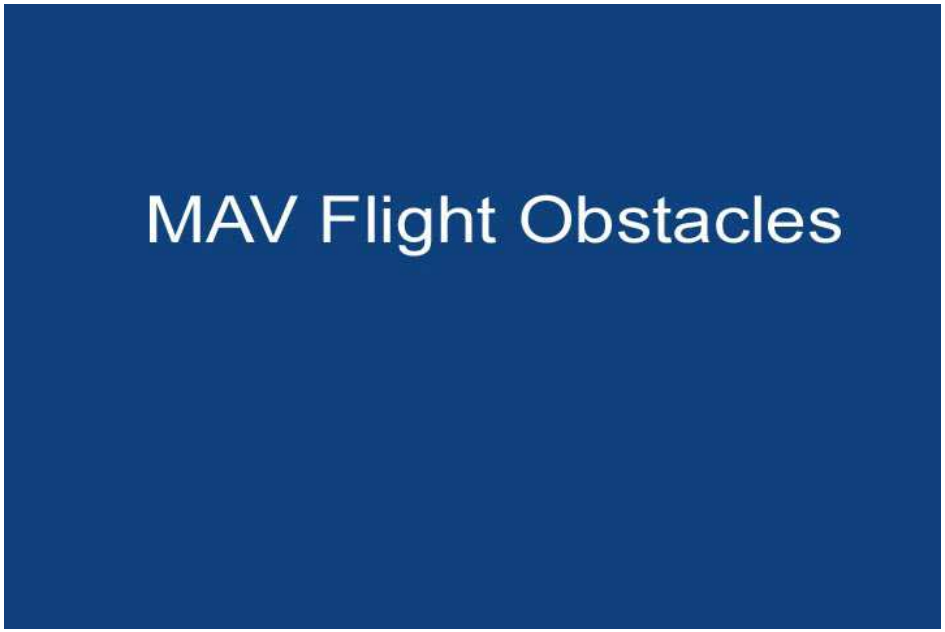
- Teleoperation (Current Practice)
  - Create a minimally acceptable state of the practice
- Semi-autonomy
  - Automation to improve safety, reduce workload
  - Reduce need for specialized worker competences
- Autonomy
  - Reduce crew needed

Designing for Teleoperation

- Minimum platform capabilities
  - Flight times of 10 minutes, quick replace batteries
  - Carry high resolution PTZ cameras
  - Payload stabilization
- Operations and strategies
  - Safe access and landing zones must be determined
  - All flights conducted within LOS
  - One elevation view at a time
- *Research Needs*
  - *Representations, visualizations of data collected*

Recommendations for Semi-Autonomy

- Waypoint navigation not desirable
- Guarded motion
  - Obstacles are in 3D and unpredictable
  - Omni-directional range sensing is needed
- Autonomous comms recovery
- Station-keeping
  - Plus take advantage of pockets of stability



Autonomy???

- Do we want it?
  - Structural survey task requires human-in-the-loop
  - LOS is required for targeting and operational safety.
  - Crew reduction: Each team member has a different focus
- Can we do it?
  - Several groups working on control side (BEAR, CMU, CSIRO,……)
  - Task planning is difficult
    - How to establish plan
    - How to execute in GPS denied environment?

Conclusions

Central findings about Semi-Autonomous MAV Ops:

- Minimum useful standoff distance is 2-5m
- Omni-directional sensor capabilities needed for obstacle avoidance
- GPS waypoint nav is unnecessary
- Requires 3 operators to 1 UAV

Current and Future Work

Obstacle avoidance

SSR-RC project: real-time vision algorithm for thin-wire UAV avoidance *(Candamo 06)*

SSR-RC project: micro-imager for UAV with optic flow avoidance algorithms for guarded motion (expect to demo in March)

Human-robot interaction

NSF SGER on HRI for UAVs for hurricane response

ARL grant (with UCF, IHMC, FAMU): Team performance and optimization in agent and human-agent teams

Special Thanks: Hancock County EOC, Dr. Elizabeth Matlack (JSU), Dave Hammond, Scott Nacheman, and the NSF

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Project Website: http://www.crasar.org/research/projects/Katrina_SGER/