The Human Challenges of Remotely Piloted Aircraft Systems

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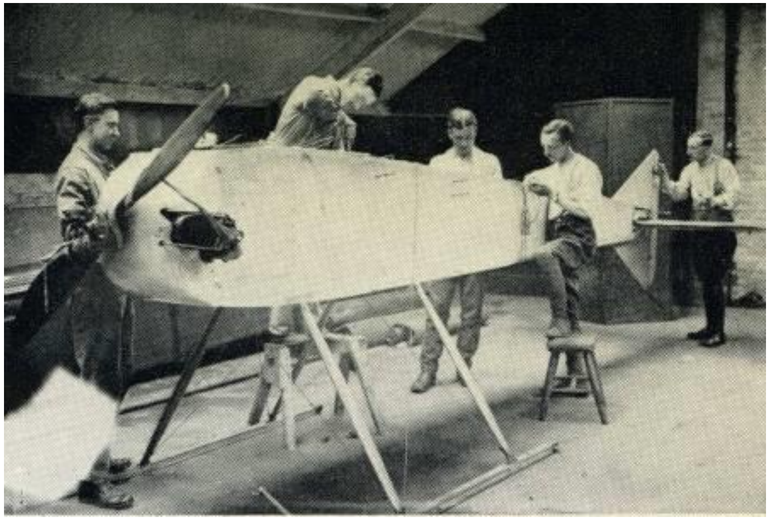
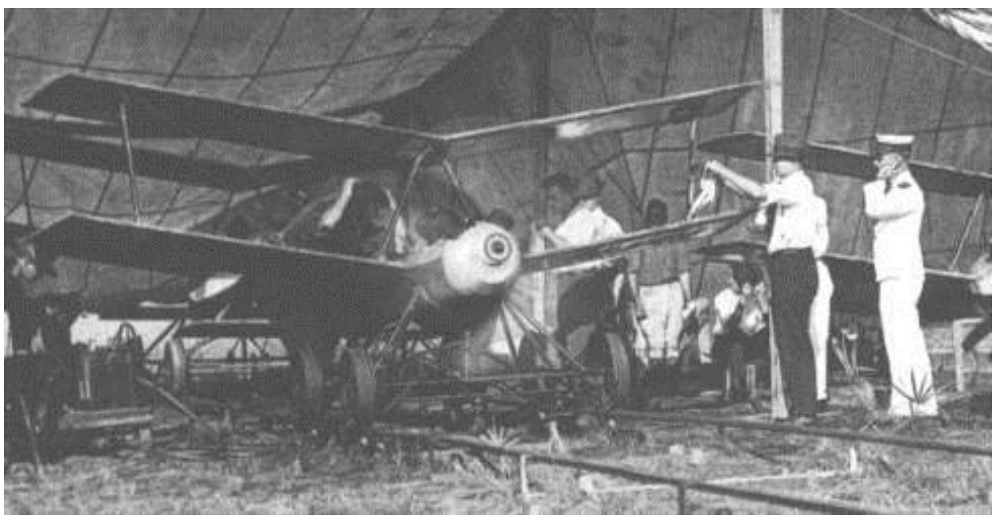
Outline

- Introduction
- Overview of RPAS human factors
- RPAS critical incident study
- Next steps



Archibald Low's radio-controlled aircraft, 1917



Kettering Bug, 1918

Denny Radioplane, 1945


NASA
ERAST
AeroVironment Inc.
HELIOS
USAF
AeroVironment

Civilian Uses of RPAS

- Advertising
- Agriculture
- Building inspections
- Cattle herding
- Construction site survey
- Customs & border protection
- Disaster response
- Environmental sensing & research
- Filmmaking
- Firefighting
- Land surveying & mapping
- Mineral exploration
- News reporting
- Parcel delivery
- Police
- Powerline, pipeline, & rail track inspections
- Real estate photography
- Search & rescue
- Ship inspections
- Telecommunications relay
- Traffic monitoring
- Wildlife monitoring

Three Types of RPAS Operations

Low level
line-of-sight

Low level beyond-
line-of-sight

All classes of civil
airspace

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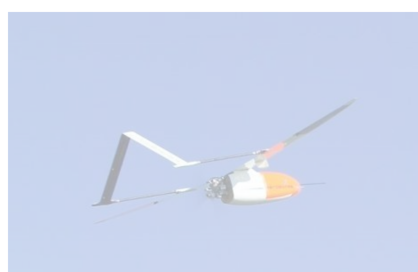


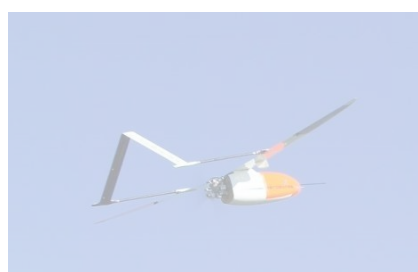
All classes of civil
airspace

Three Types of RPAS Operations

FAA Assumptions
Instrument Flight Rules
Controlled by a remote pilot
Not autonomous
Complies with ATC instructions

Low level line-of-sight

Low level beyond-line-of sight



All classes of civil airspace

Accident Record

- Army <u>accident</u> rates[1]:
  - Unmanned aircraft: 49 per 100,000 hours
  - Manned aircraft: 4 per 100,000 hours
- USAF <u>hull-loss</u> rates[2]:
  - MQ-9: 4 per 100,000 hours flown
  - Manned aircraft: 0.4 per 100,000 hours flown
- Small civilian RPA <u>hull-loss rate</u>:
  - ~ 300 per 100,000 flight hours

1. Prather, C. (2013). Online report of Army aircraft mishaps. *Flightfax, 26*. Retrieved from www.safety.army.mil
2. United States Air Force. (2015). *Q-9 flight mishap history*. Retrieved from http://www.afsec.af.mil

Predator B Accident at Nogales

Source: NTSB

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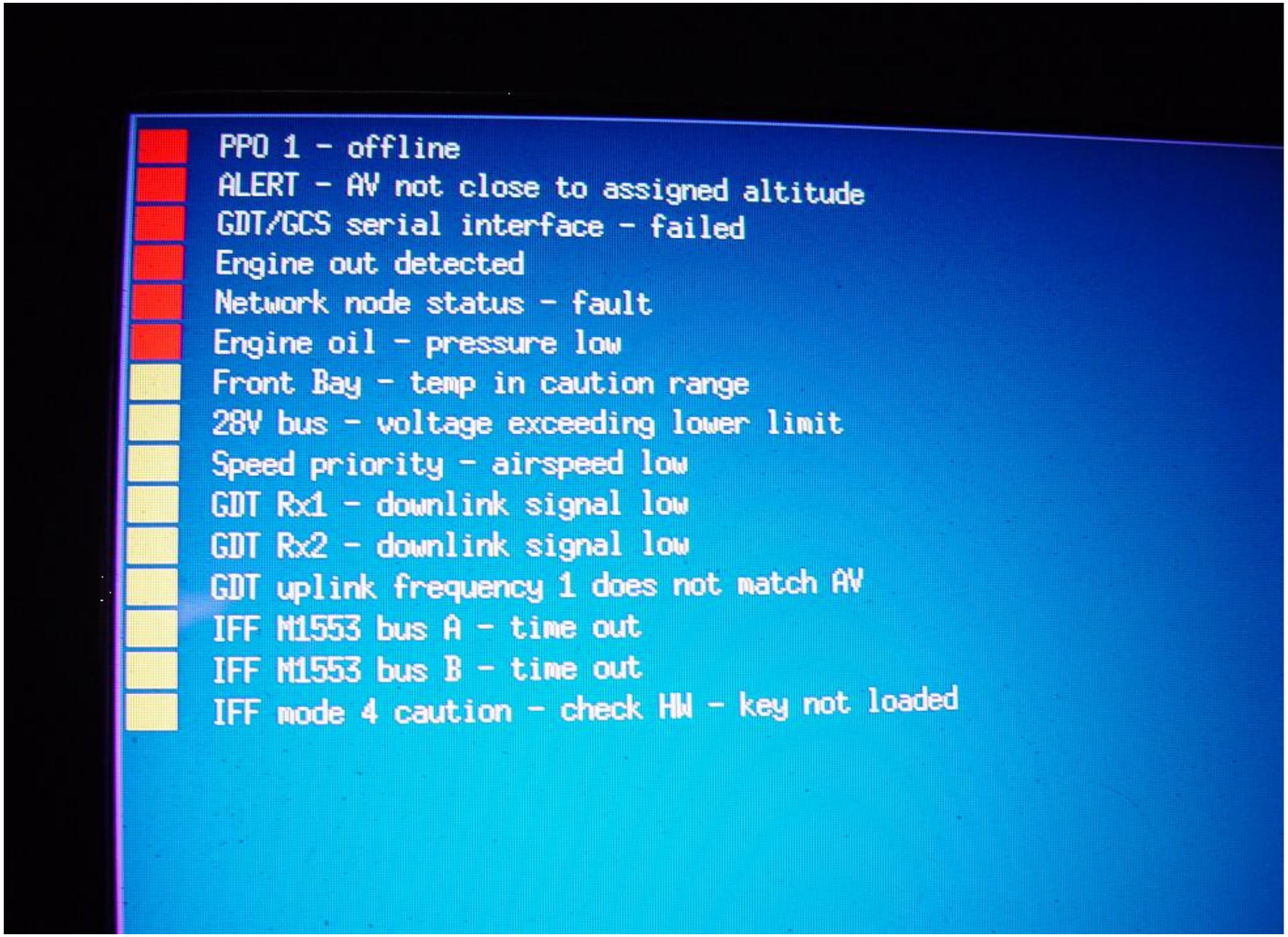
Predator B Accident at Nogales



Source: NTSB

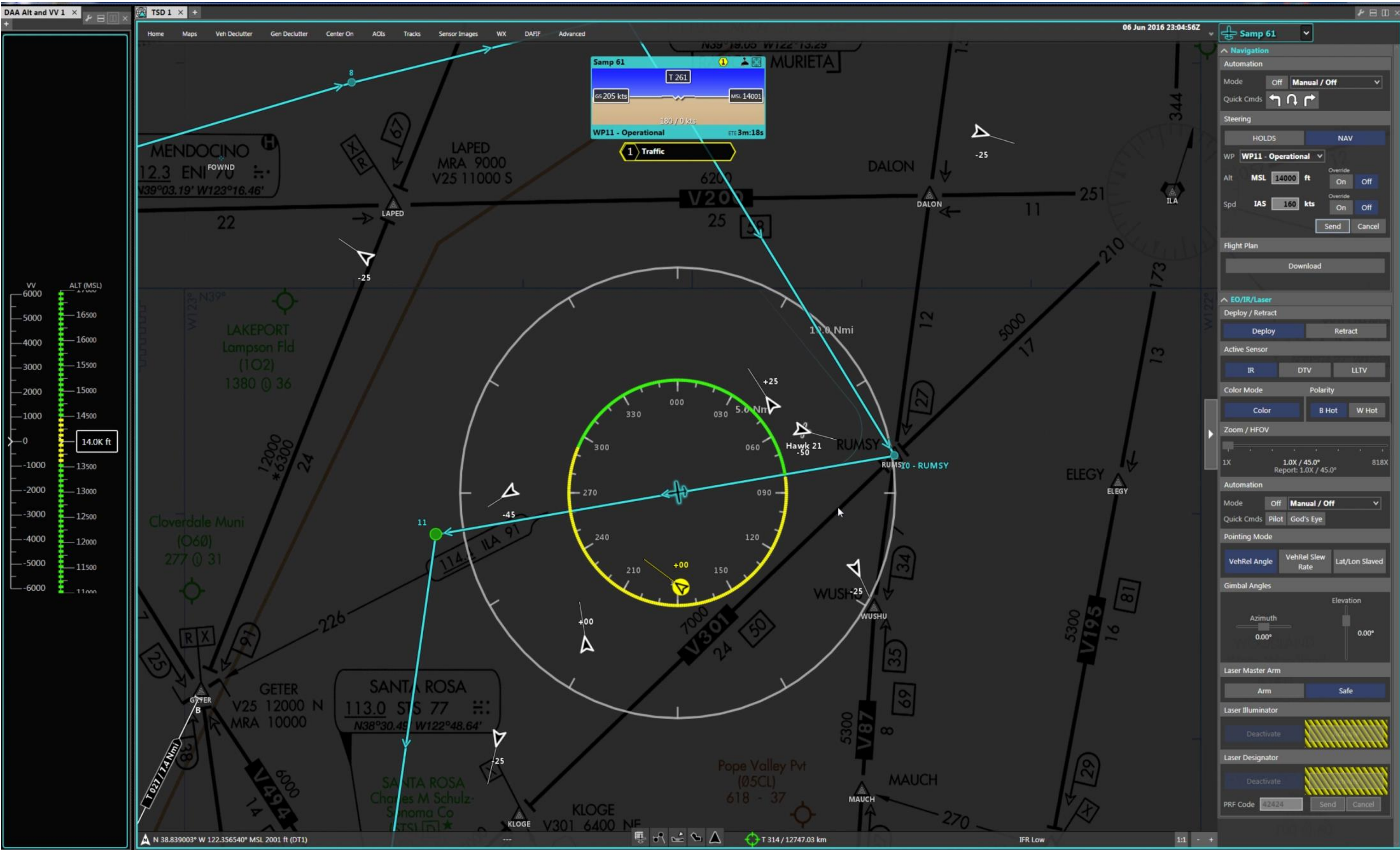
Overview of RPAS Human Factors

1. Reduced sensory cues
2. Teleoperation via radio link
3. Remote pilot station
4. In-flight transfer of control
5. Flight termination

1. Reduced Sensory Cues

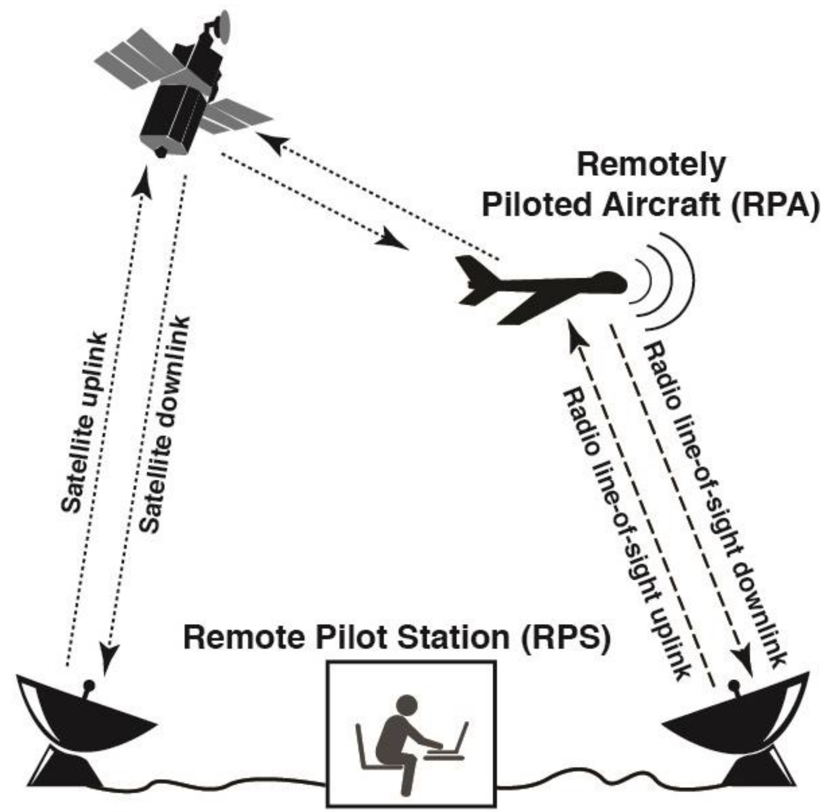
- Lack of natural cues (e.g. visual, auditory, haptic)
- “Soda straw” view from on-board camera
- No “see and avoid”

Detect and Avoid Display



2. Teleoperation Via Radio Link

- Loss of link
- Latencies
- Link management
- Lost link procedures



3. Remote Pilot Station (RPS)

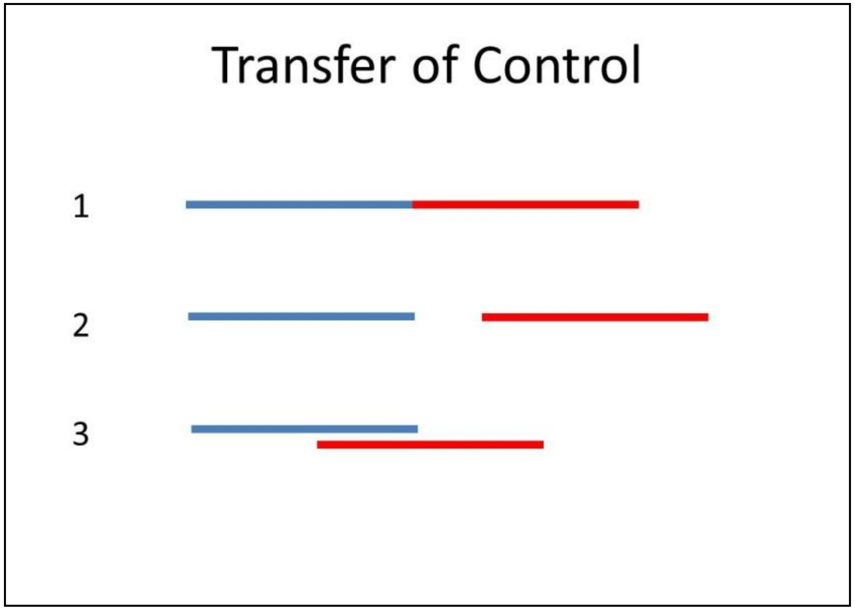
Laptop Pilot Station

RPS Interfaces

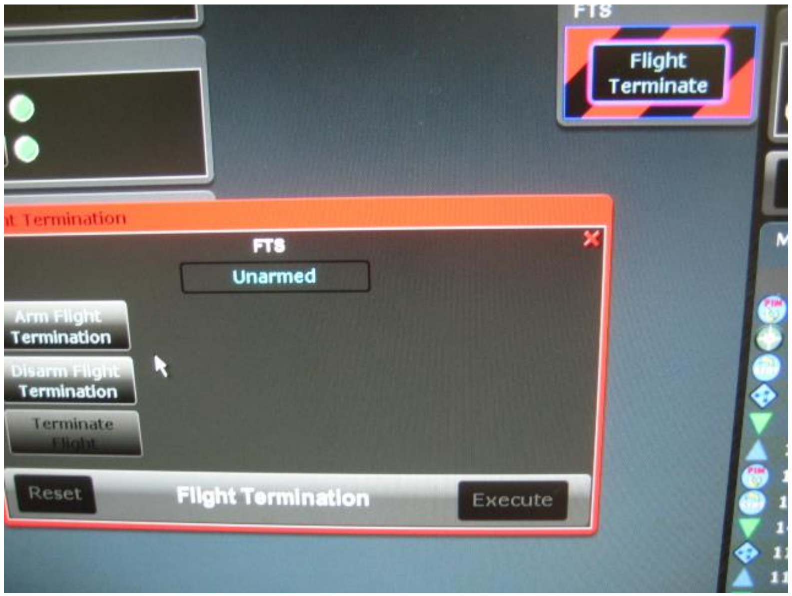
- Physical ergonomics
  - Unreachable controls
  - Difficult-to-read fonts and colors
  - Critical controls placed next to non-critical controls
  - Proliferation of displays
- Cognitive ergonomics
  - Complicated menu structures
  - Inadequate feedback
  - Reliance on text displays
  - Multi-function controls

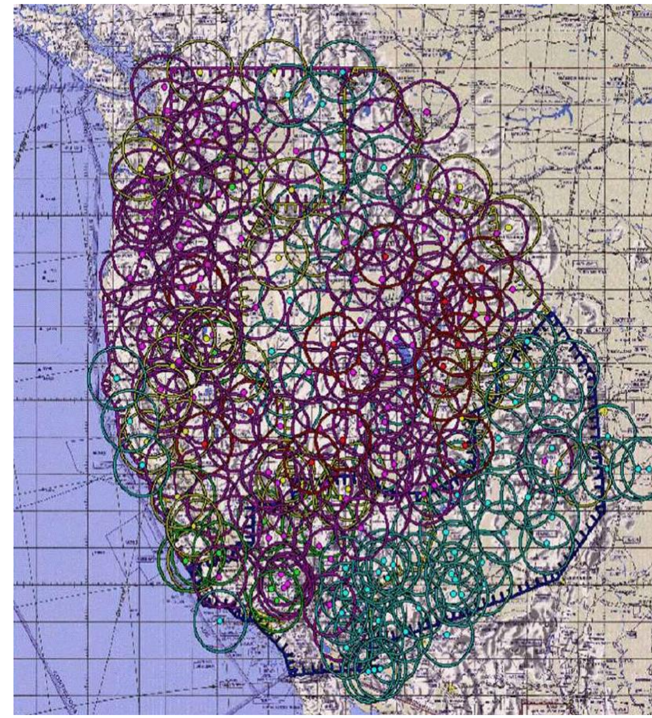
4. In-flight Transfer of Control

- Handovers at same console
- Control frequency changes
- Transfers between consoles in same RPS
- Transfers between RPS



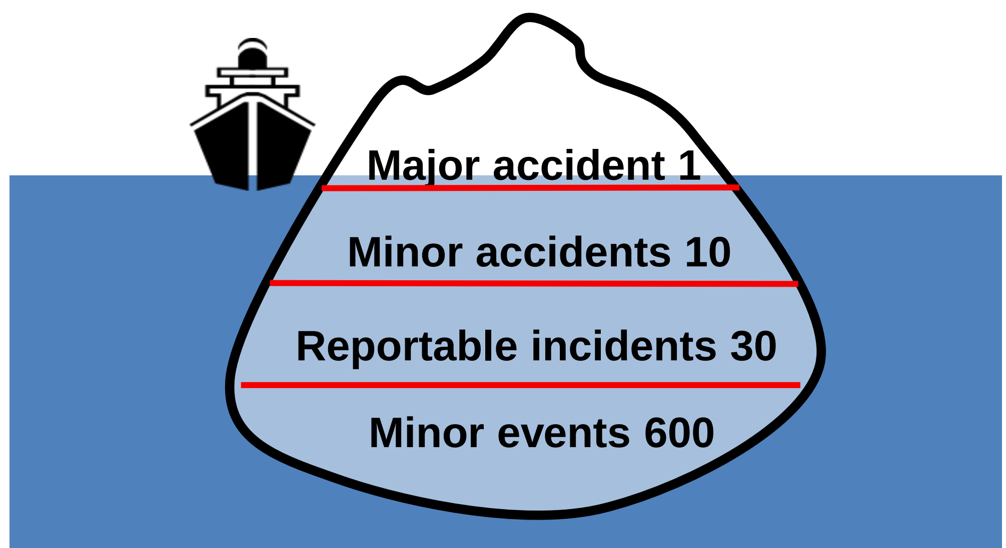
5. Flight Termination





RPAS Critical Incident Study: Rationale

- "Tombstone safety" in the 20th century
- Lack of data on minor RPAS events

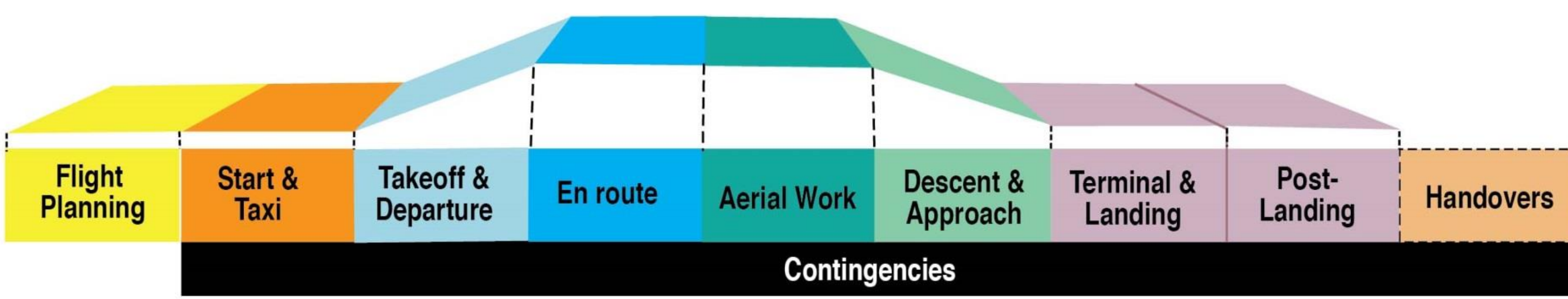


RPAS Critical Incident Study: Goals

- Examine the feasibility of a method to collect the operational experiences of RPAS pilots
- Provide independent and complementary data to supplement NASA simulations and flight tests

RPAS Critical Incident Study: Approach

- Focus groups with 2-3 pilots at a time
- Participants asked to recall events experienced while operating a remotely piloted aircraft
  1. A hazardous situation or error
  2. The rectification of a hazardous situation or error
- Only reports that can be made public

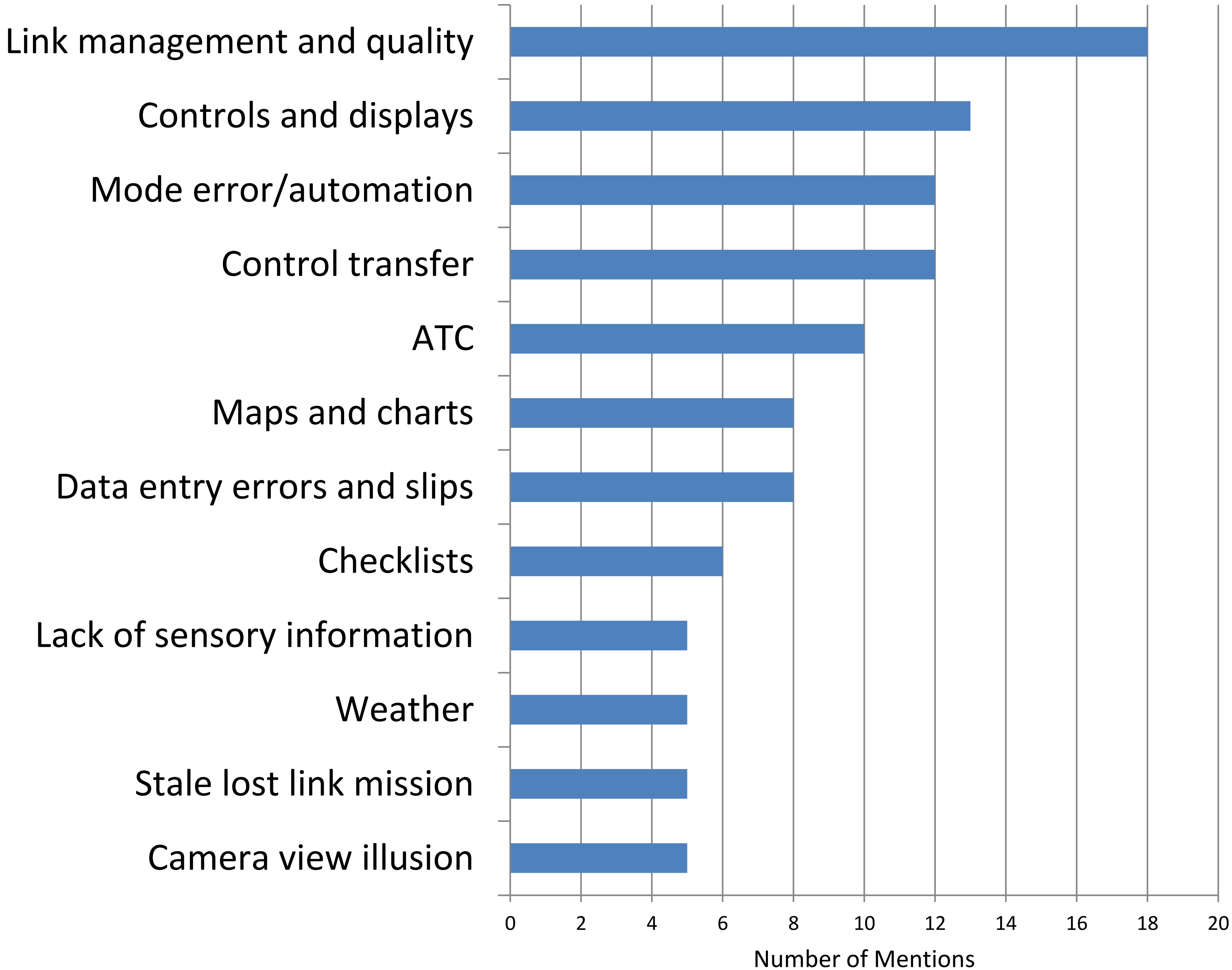


Preliminary Results

- 23 participants
- 90 incidents described
- Weight classes of the remotely piloted aircraft:

Aircraft max takeoff weight	*# of reports*
Less than 400 lbs	17
2000-15,000 lbs	60
Greater than 15,000 lbs	13

Problems Mentioned in Reports

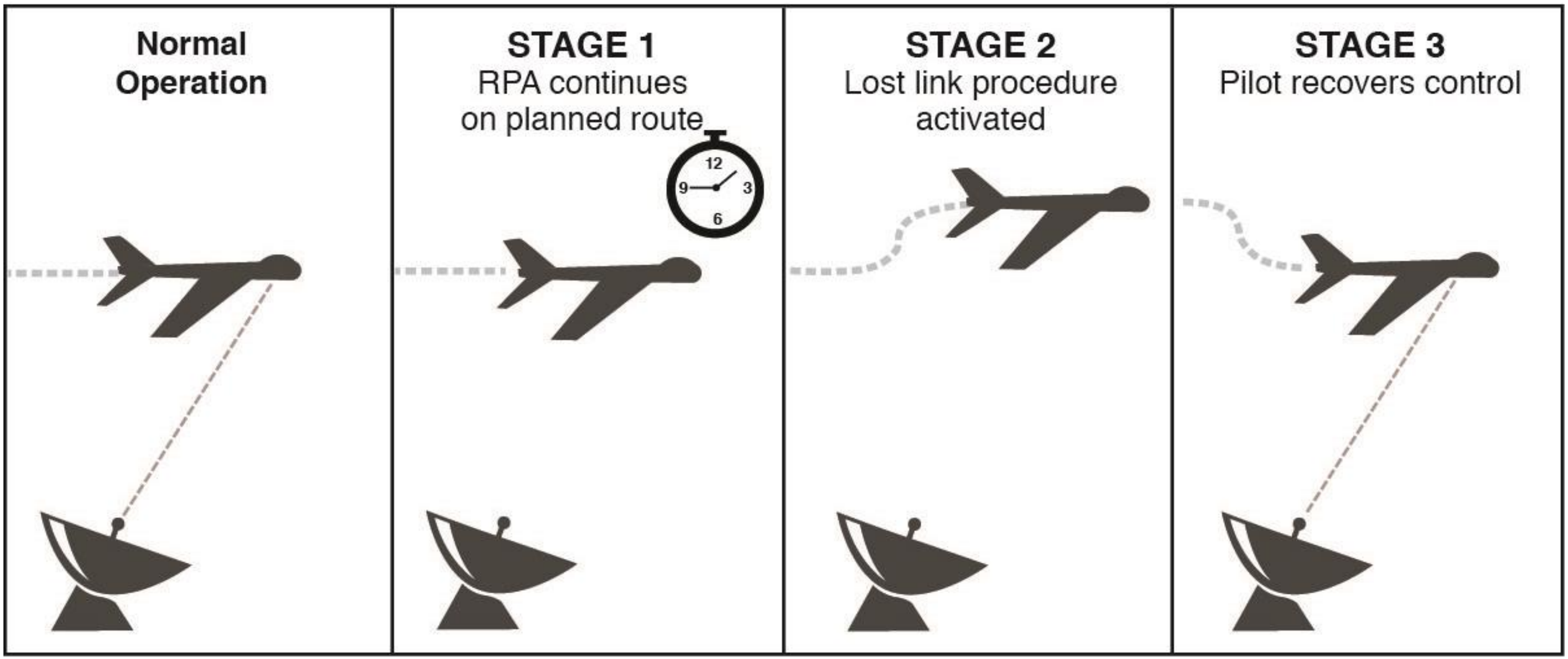


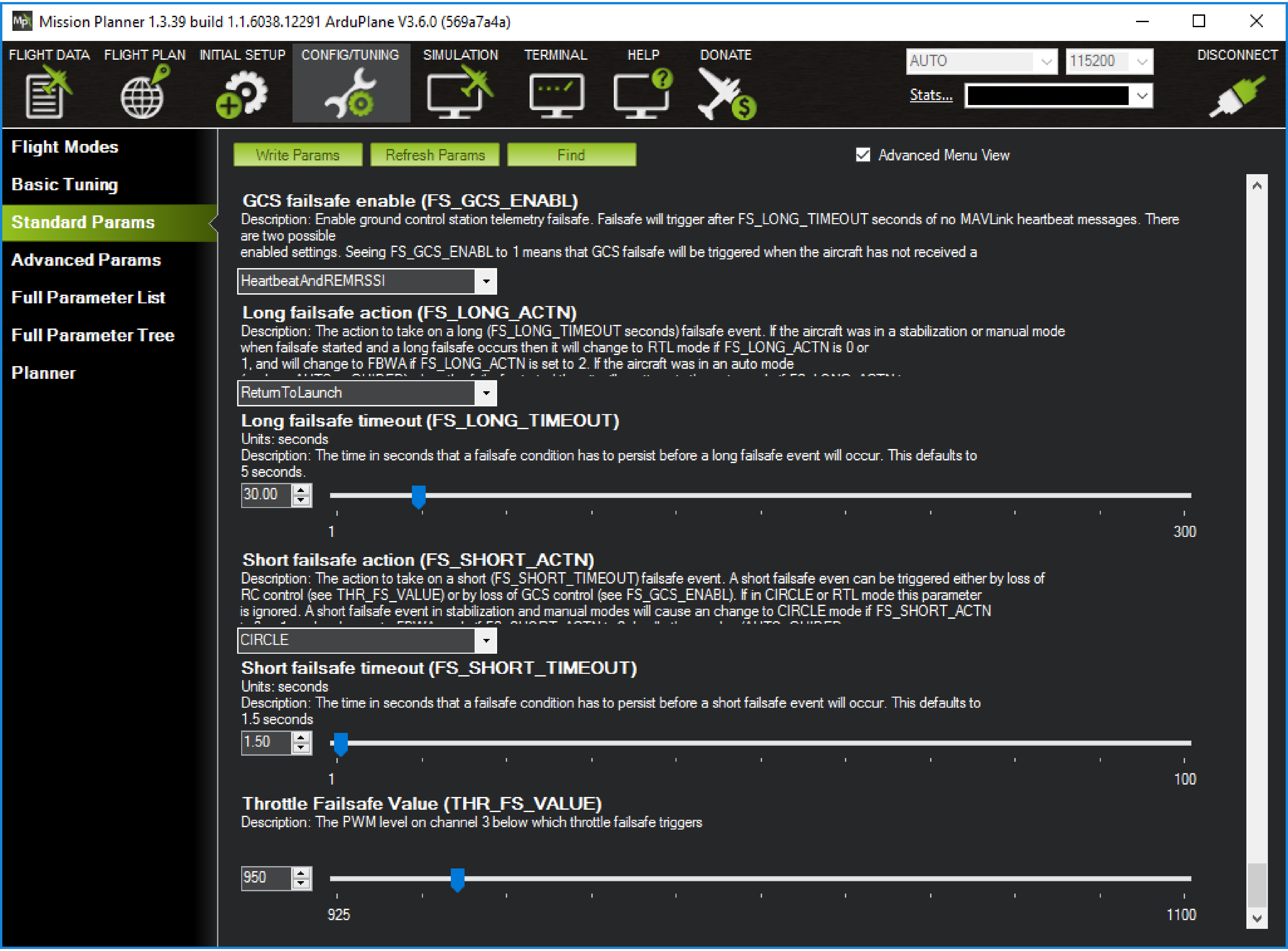
Example: Lost Link

“We were flying really far out … about 90 kilometers from the antenna. But I passed some random mountain peak for about one second and the aircraft went into emergency mode. Luckily I had the correct emergency mode programmed. If I didn't, I could've lost the aircraft.”

RPAS pilot report

Stages of Lost Link




Mission Planner 1.3.39 build 1.1.6038.12291 ArduPlane V3.6.0 (569a7a4a)
FLIGHT DATA
FLIGHT PLAN
INITIAL SETUP
CONFIG/TUNING
SIMULATION
TERMINAL
HELP
DONATE
AUTO
115200
Stats...
DISCONNECT
Flight Modes
Basic Tuning
Standard Params
Advanced Params
Full Parameter List
Full Parameter Tree
Planner
Write Params
Refresh Params
Find
Advanced Menu View
GCS failsafe enable (FS_GCS_ENABL)
Description: Enable ground control station telemetry failsafe. Failsafe will trigger after FS_LONG_TIMEOUT seconds of no MAVLink heartbeat messages. There are two possible
enabled settings. Seeing FS_GCS_ENABL to 1 means that GCS failsafe will be triggered when the aircraft has not received a
HeartbeatAndREMRSSI
Long failsafe action (FS_LONG_ACTN)
Description: The action to take on a long (FS_LONG_TIMEOUT seconds) failsafe event. If the aircraft was in a stabilization or manual mode
when failsafe started and a long failsafe occurs then it will change to RTL mode if FS_LONG_ACTN is 0 or
1, and will change to FBWA if FS_LONG_ACTN is set to 2. If the aircraft was in an auto mode
ReturnToLaunch
Long failsafe timeout (FS_LONG_TIMEOUT)
Units: seconds
Description: The time in seconds that a failsafe condition has to persist before a long failsafe event will occur. This defaults to
5 seconds.
30.00
1
300
Short failsafe action (FS_SHORT_ACTN)
Description: The action to take on a short (FS_SHORT_TIMEOUT) failsafe event. A short failsafe even can be triggered either by loss of
RC control (see THR_FS_VALUE) or by loss of GCS control (see FS_GCS_ENABL). If in CIRCLE or RTL mode this parameter
is ignored. A short failsafe event in stabilization and manual modes will cause an change to CIRCLE mode if FS_SHORT_ACTN
CIRCLE
Short failsafe timeout (FS_SHORT_TIMEOUT)
Units: seconds
Description: The time in seconds that a failsafe condition has to persist before a short failsafe event will occur. This defaults to
1.5 seconds
1.50
1
100
Throttle Failsafe Value (THR_FS_VALUE)
Description: The PWM level on channel 3 below which throttle failsafe triggers
950
925
1100

Example: Lost Link Timer

"The airplane … made many turnarounds due to it being out of link then … it would reacquire and … return on mission. This affected fuel burn. [So I] set time-out feature just short of the actual mission duration."

RPAS pilot report

Example: Lack of Sensory Information

“We fly based on digital gauges. We don't hear or feel anything, like RPM changes …. The aircraft is supposed to level off, at say, 5,000 ft … As opposed to a real aircraft [where] you can feel the airplane leveling off, I couldn't determine if it was still climbing until I noticed it was 300 ft past its command altitude.”

RPAS pilot report

Stale Lost Link

- Pilot awareness of lost link mission
- Lost link mission needs regular updating
- Lost link mission can be a form of “automation surprise”

Example: Stale Lost Link

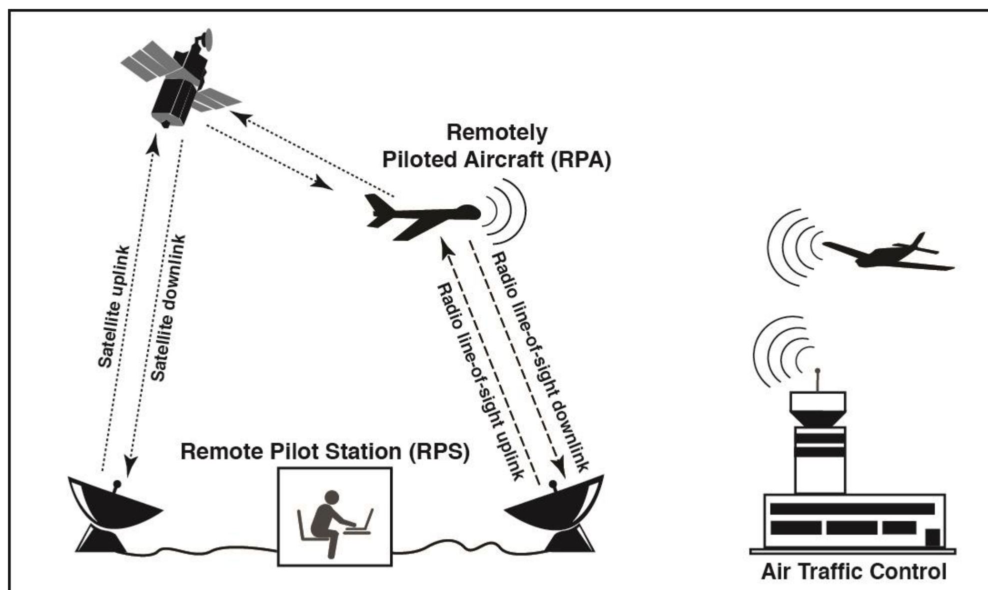
"At the beginning of the flight, the lost link procedure was valid, but the procedure was not updated later in the flight. At one point, had the lost link procedure been activated, it would've had the aircraft fly through terrain in an attempt to reach the next waypoint. However, the aircraft didn't lose link and the error was caught in the handover to the next set of operators."

RPAS pilot report

Example: Voice Latency

"There is a delay between clicking the press-to-talk and talking. This is very difficult to manage when in very busy airspace, and listening for a gap to talk. Sometimes by the time we press the talk button, with the satellite delay, the gap is gone and we step on other aircraft."

RPAS pilot report



Controls and Displays

- Some RPS interfaces appear to be particularly error-productive
- Shared payload and flight controls
- Keyboard and consumer interfaces

Example Narrative: Keyboards

"… an operator placed his manual on top of [the keyboard]. Accidently, this activated the GUI. Then more pressure was applied through handling the manual, on the space bar. As a result, it highlighted and armed, through several steps, the flight termination button. Luckily, the operator saw the countdown and caught it in time to deactivate this command."

RPAS pilot report

Example: Data Entry Errors and Slips

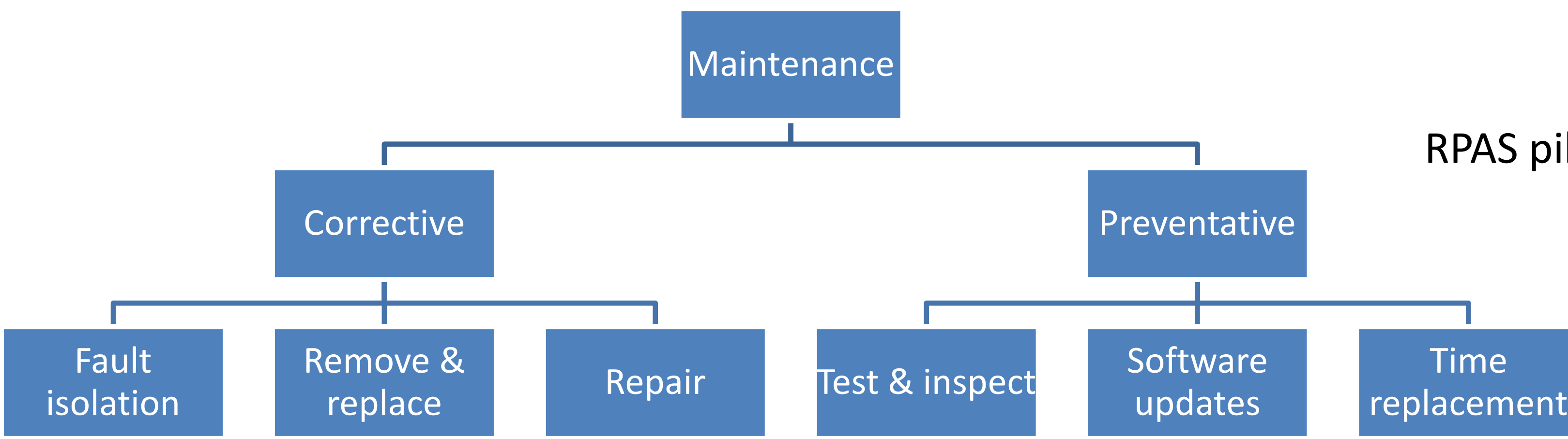
"I went to put the gear down, but instead I turned the SAS [Stability Augmentation System] off using the red emergency button. The aircraft went into a 20-degree bank and 5-degrees nose down. I was able to recover the airplane. I had developed muscle memory with the activation of the SAS disengagement button."

RPAS pilot report

Accessibility of RPS

"In manned aircraft it is clear who is in command, but with UAS operations, there are multiple people who have a sense of responsibility for the aircraft. So when there is something that needs attention many people run to the GCS [Ground Control Station]."

RPAS pilot report



Example: Mode Error during Control Station Transfer

"During preflight, handover checks were being done … we had the aircraft engine at idle with the parking brake set, but when the radio handover switched to XXX, he didn't have the parking brake set and the power was set at 80% …. The result was the engine revving up, and the aircraft jumping its chocks."

RPAS pilot report

Example: Unintended Transfer

"I was preparing to take control of the aircraft from [another pilot station]. The transmitters from my GCS were accidently left on. When I slewed the directional antenna to get the picture of the aircraft (the down link info), this automatically gave me control of the aircraft. I was not intending to take control of the aircraft at this time."

RPAS pilot report

Example: Camera View Illusion

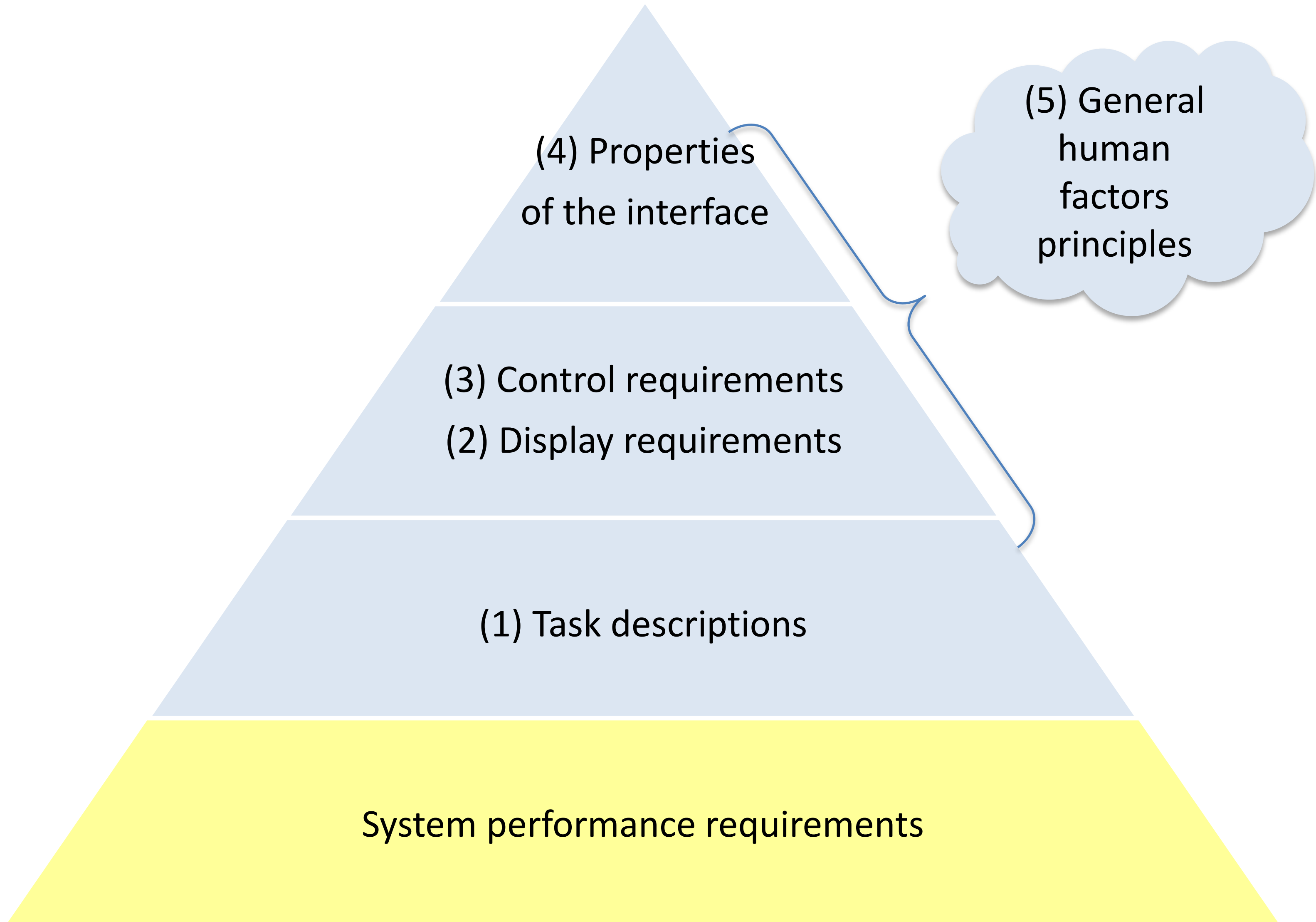
"Depending on how I do the landing …. [the moveable sensor camera] …will be used to make sure that we clear the turns. But sometimes, the sensor operator will move the camera, which will make it look like I'm turning but I'm actually not turning. So I have to concentrate and make sure I don't respond to that erroneous camera view."

RPAS pilot report

Next Steps

- Continuing to collect RPAS incidents
- Results are being used to inform design guidelines for RPAS control stations
- Incident reports are helping to identify under-examined topics

Applying the Lessons to RPS Guidelines



Applying the Lessons to RPS Guidelines

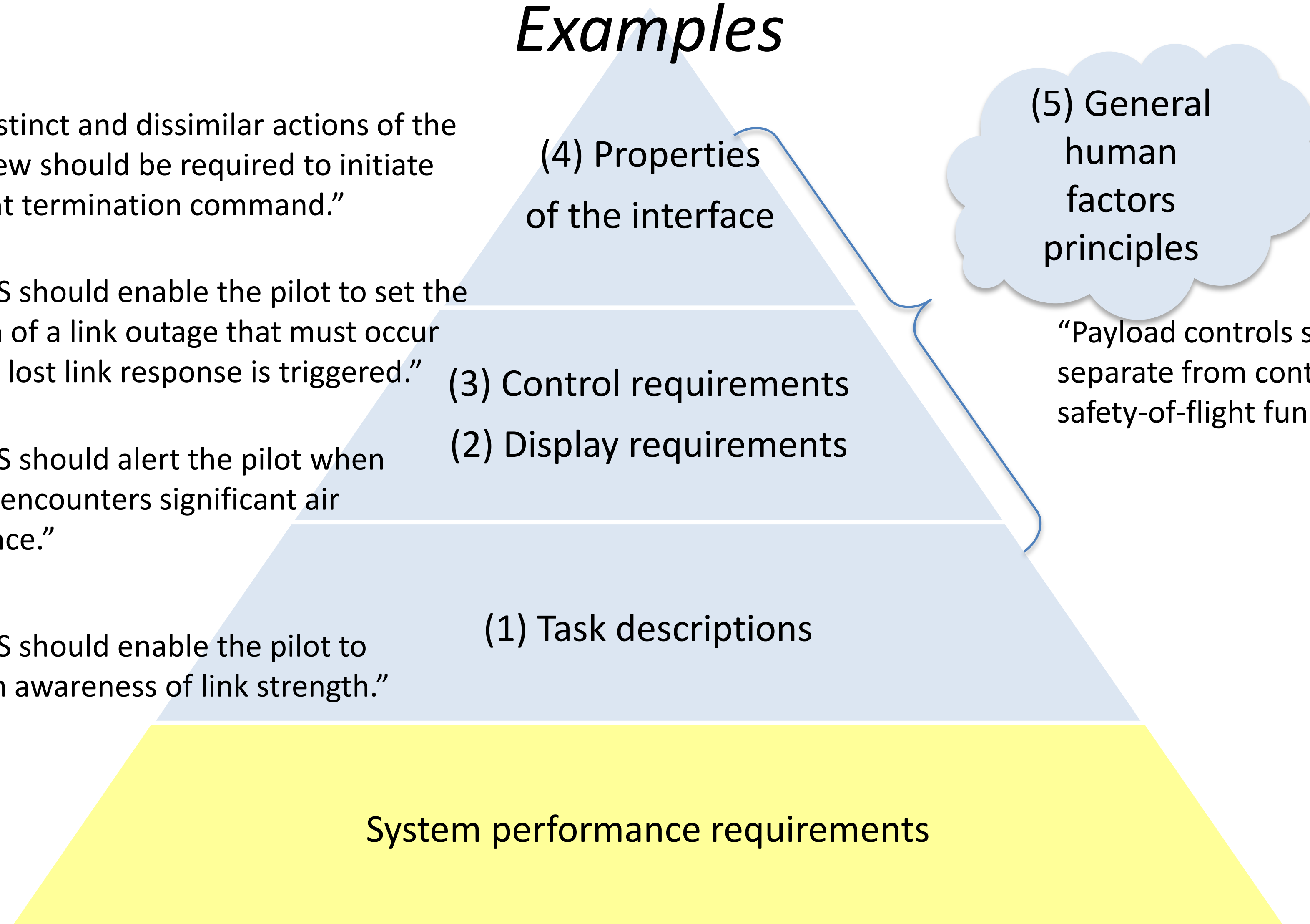
Examples

"Two distinct and dissimilar actions of the RPAS crew should be required to initiate the flight termination command."

"The RPS should enable the pilot to set the duration of a link outage that must occur before a lost link response is triggered."

"The RPS should alert the pilot when the RPA encounters significant air turbulence."

"The RPS should enable the pilot to maintain awareness of link strength."



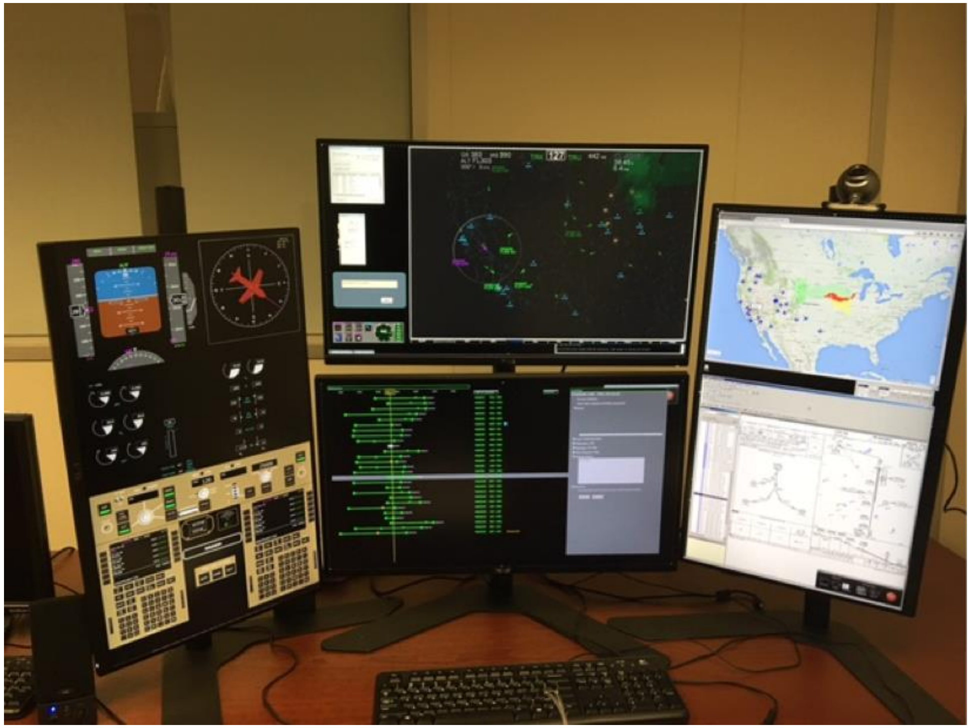
"Payload controls should be separate from controls with safety-of-flight functions."

Under-examined Topics

1. Reduced sensory cues
   – How does reduced sensory information affect threat & error management?
2. Teleoperation via radio link
   – What does ATC need to know about link interruptions?
   – How much voice delay is tolerable for pilot communications?
   – How do humans positively contribute to highly-automated, teleoperated systems?
3. Remote pilot station
   – How does the accessibility of the RPS change team dynamics?
   – What maintenance tasks should be permitted while an RPS is controlling an aircraft?
4. In-flight transfer of control
   – What are best practices for control transfers?
   – What design features are needed to support control transfers?
5. Flight termination
   – What information is needed to support flight termination decision making?

A Final Thought

- Will there be a convergence between conventional aircraft and RPAS?



References

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