Headquarters U.S. Air Force

Integrity - Service - Excellence

Remotely Piloted Aircraft (RPA) Operations

U.S. AIR FORCE

Kelly Lee
Richard Greenwood
RPA Investigators
Air Force Safety Center

One Man's Vision

"We have just won a war with a lot of heroes flying around in planes. The next war may be fought by airplanes with no men in them at all . . . Take everything you've learned about aviation in war, throw it out of the window, and let's go to work on tomorrow's aviation. It will be different from anything the world has ever seen."

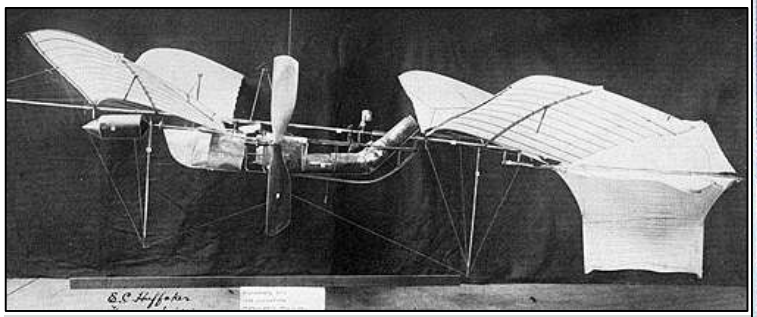
Gen Hap Arnold, USAAF
VJ Day, 1945

Overview

- **Challenges of RPA Investigations**
  - RPA
    - System
    - Operations
    - Day in the life
    - Sensors
    - Raid (Video)
    - Growth
    - Future

Evolution of RPA in America
Proxy…Prey…Prowler…Predator

1896	1918	1941	1951	1975	1989	1995	2002	2006	Future
First Flight	Liberty Eagle	OQ-2 Radioplane	XQ-2 Firebee	AQM-34L "Tom Cat"	GA UAV GNAT 750	USAF RQ-1	MQ-1 Predator	MQ-9 Reaper	



Langley's Aerodrome No. 5

Liberty Eagle/Kettering "Bug"

1945

OQ-2

MQ-9

RQ-1

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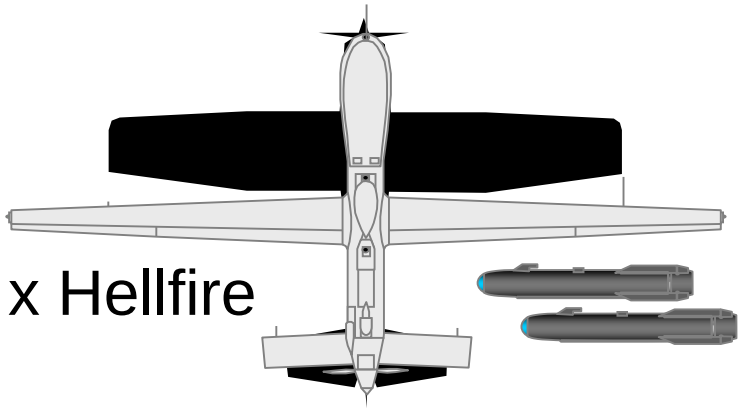
How the RPAs get it done

MQ-1/MQ-9 Comparison

MQ-1

C-172 Size



2 x Hellfire

Wingspan: 49 FT Length: 26 FT

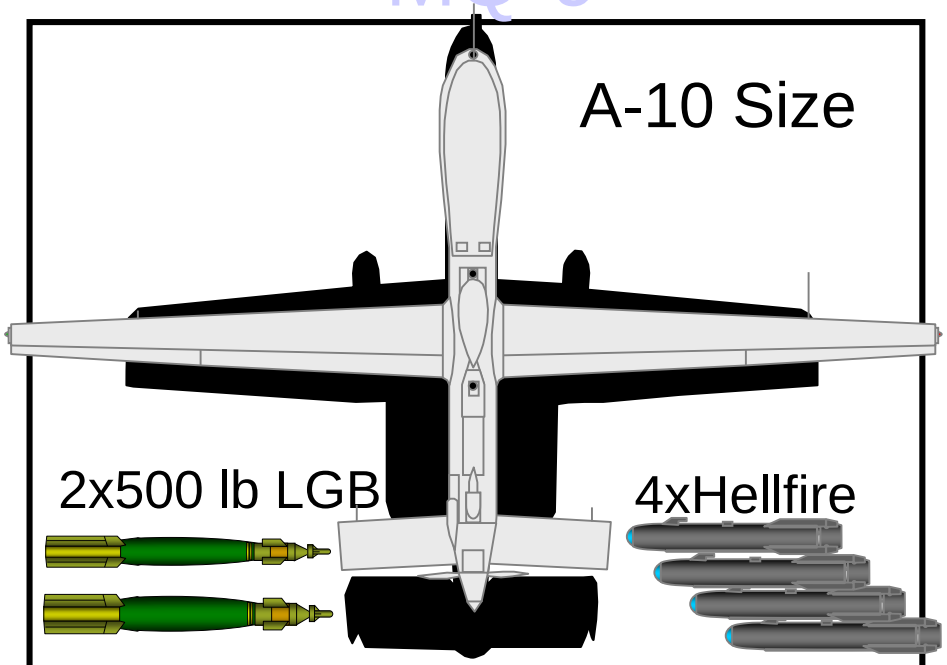
Max Speed: 120 KT Endurance: 24 hrs

Max Altitude: 25,000 ft MSL

Payload: 300 lbs (2 hard points)

MQ-9

A-10 Size



2x500 lb LGB

4xHellfire

Wingspan: 64 FT Length: 36 FT

Max Speed: 240 KT Endurance: 18 hrs

Max Altitude: 50,000 ft

Payload: 3000 lbs (6 hard points)

The Rest of the System

Predator/Reaper System 24/7/365 Combat Air Patrol

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The "Cockpit"

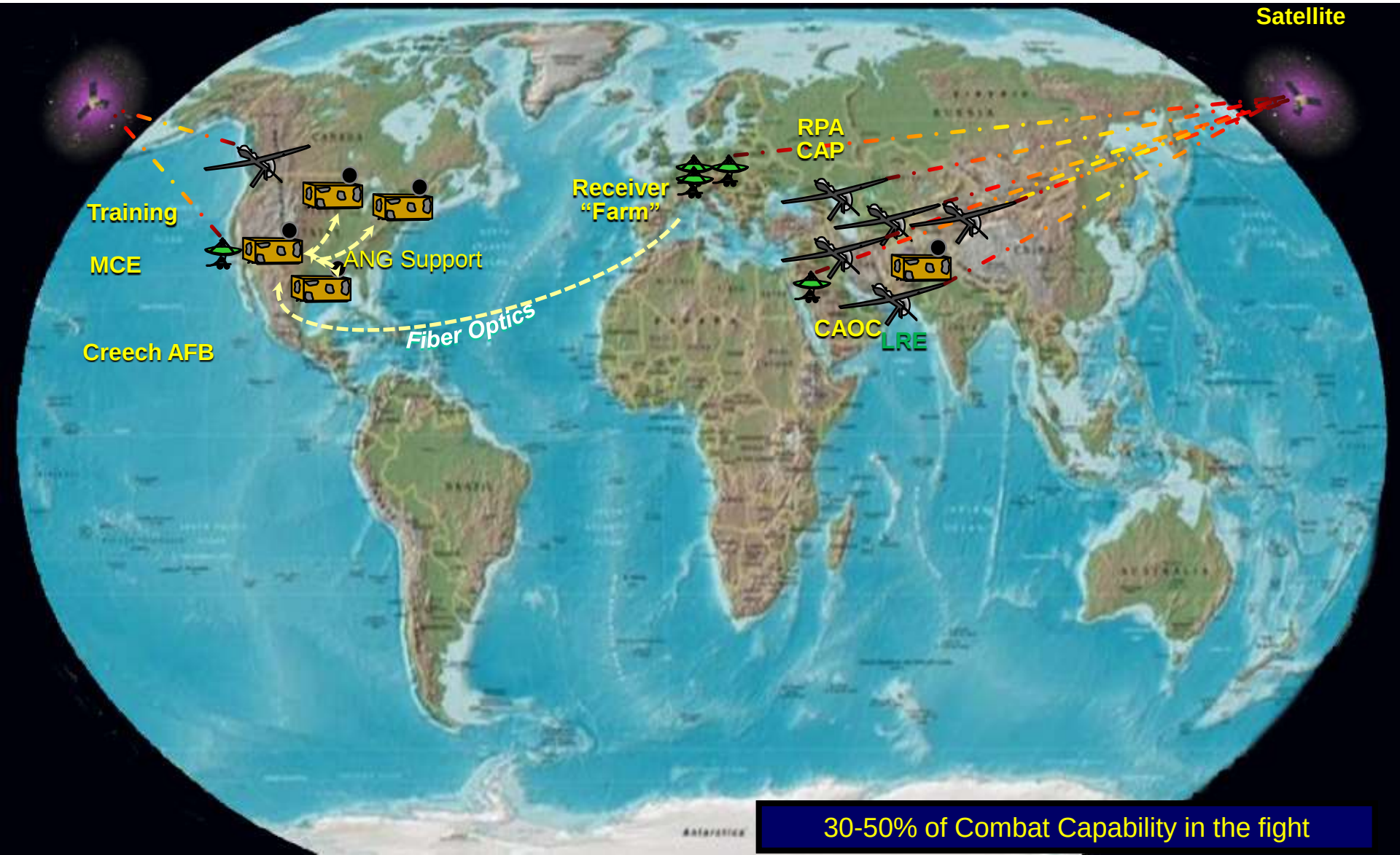
Line of Sight Ops
(1995)

30-50% of Combat Capability in the fight

Beyond Line of Sight Ops
(2001)

30-50% of Combat Capability in the fight

Remote Split Ops
(2003-8)



30-50% of Combat Capability in the fight

RPA
- Operations

- **Remote Split Operations (RSO)**
  - Multiple Flight Crews in diverse geographic locations
    - Launch and Recovery Element (LRE)
    - Mission Control Element (MCE)
  - Multiple Maintainers in diverse geographic locations
    - Maintenance of Air Vehicle and Ground Control Station (GCS)
- **Why RSO with RPA?**
  - Approximately 1/3 the forward deployed footprint
  - Dwell is not an issue – can be located anywhere with MCE operations (Creech, NY ANG, wherever…)
  - 100% of operational resources in the fight
  - Battlefield continuity

RPA
- A Day in the Life Of …

- RPA FTU → Combat Squadron → CMR Program
- Flight/Shift Assignments
- Shift Work (5-3, 6-3, 5-2)
  - Daily Mission Brief/Intel Updates/Spins Review
  - 6 hour flight times average per shift (3 and 3)
  - Fight in up to 3 AORs a shift coordinating with people all over the world to prosecute targets
  - Work for joint/foreign supported units doing ISR/CAS/CSAR/Killbox Ops/Humanitarian
  - Debrief and head back home
  - Limited TDY's/Deployments
- Normal Additional Duties (Shop Chief, Flt/CC, Weapons/Tactics, Group/WG Jobs, WIC)

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ISR Capabilities

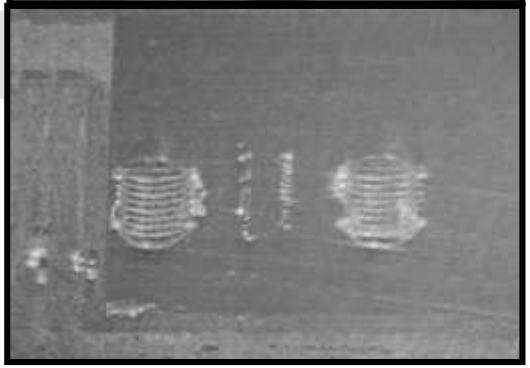
Predator/ Reaper Sensor Details

- EO—Day Only
  - 6-Step, 155x Optical Zoom
  - 2x, 4x Digital Zoom
- IR—Day, Night
  - 3 to 5 Micron (Med IR)
  - 4-Step 56x Optical Zoom
  - 2x, 4x Digital Zoom
- SAR—Day, Night, All Wx
  - Resolution: 0.3 m
  - Swath Width: 600-1100 m

EO

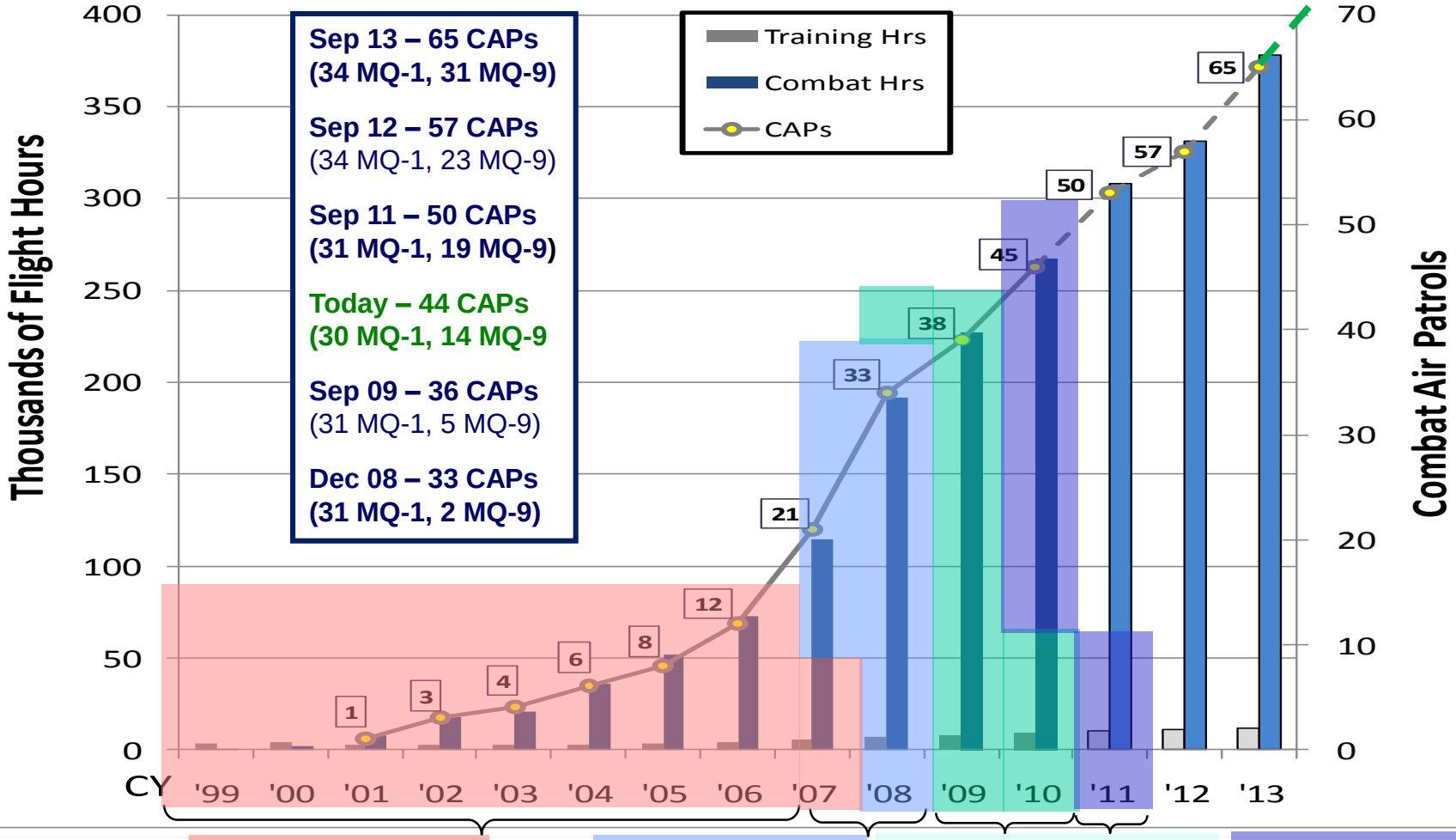
IR

SAR



RPA
- Close Air Support - Raid

RPA CAP Growth
(MQ-1, MQ-9)



1st 250k hours
(1995 – May 07)

2nd 250k hours
(May 07 – Nov 08)

3rd 250k hours
(Dec 08 – May 10)

4th 250k hours
(Projected: May 10 – May 11)

Current and Emerging Missions

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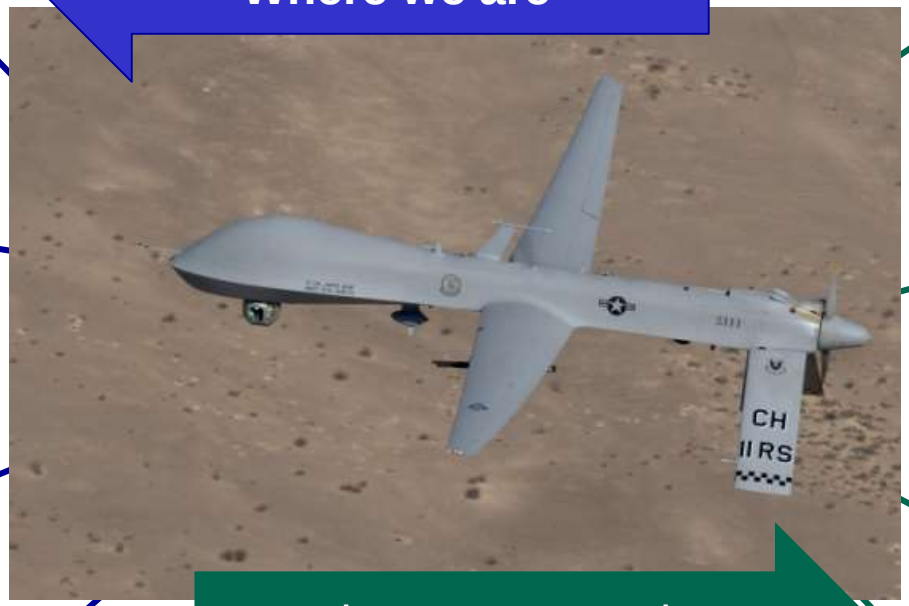
Where we are

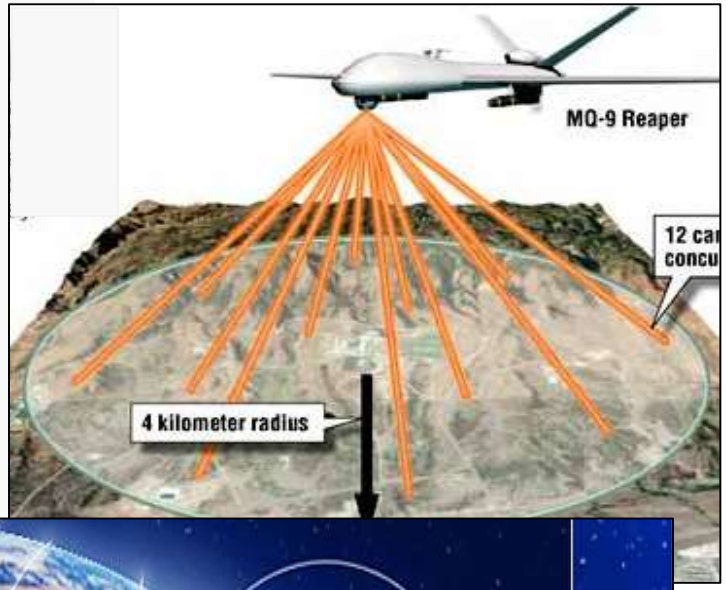


Where we are going

Always Supporting the Joint Force Commander

Future Capabilities

- Advanced Sensors
  - GMTI/VADER/GORGON STARE/WAAS
- Advanced Systems
  - MSCT/TDF
    (Multi-Source Corr. Tracker/Tactical Display Framework)
- Mass and Maneuver
  - Multi-ship Ops
- Lynx SAR
  - Untapped Current Capability
- Redundancy
- Advanced Weapons
  - Self Protection
    - AIM-9x



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QUESTIONS?

Investigations

Kelly Lee
Richard Greenwood
RPA Investigators
Air Force Safety Center

Investigations

- Overview
  - Dataloggers
  - Video
  - Wreckage
  - Challenges
  - Case Studies

Dataloggers

- **Dataloggers, the MQ-1/MQ-9 investigators primary tool.**
  - Data packets in the Up link and Down link (or Command Link and Control Link) to / from the aircraft are all recorded, as are operator control movements and switch positions in the Ground Control Station (GCS). These are stored in the GCS for later download and are referred to as the "Dataloggers"
  - The investigator has access to much of the same data you would get from a Flight Data Recorder. Major difference it that when the RPA loses link with the GCS, no more data from the RPA is recorded. The aircraft may continue to fly lost link for several hours. You will have no data from the aircraft during this time, only the ground crews futile attempts to get control back
  - Datalogger parameters have sample rates of between 1 and 20 Hz, depending on the parameter
  - Over 1400 parameters available

Dataloggers

- **Reading the files**
  - Dataloggers are analyzed with a software program called “Signal Plotter”
    - Developed by engineers at General Atomics for development work, not for accident investigations
    - Not currently “Air Force Approved” Software
    - Data can be exported to Google Earth and other programs to show flight paths

Dataloggers

- **The data is grouped into three set of parameters**
  - The A Files. Data which is recorded at 20Hz, usually consists of control and aircraft movements. Some examples:
    - Pitch Stick Pi - Control stick movement in the GCS sent to the aircraft requesting a pitch up or down. Generated in the GCS
    - Pitch – The actual pitch angle of the aircraft. Generated by the aircraft
    - Roll Stick Pi - Control stick movement in the GCS sent to the aircraft requesting a roll left or right. Generated in the GCS
    - Roll – The actual roll angle of the aircraft. Generated by the aircraft.
    - Normal Accel – The vertical (Z) G load experienced by the aircraft. Very useful in hard landing mishaps or to show turbulence in weather related mishaps. Recording limit is +/- 5.0 G's. Generated by the aircraft.

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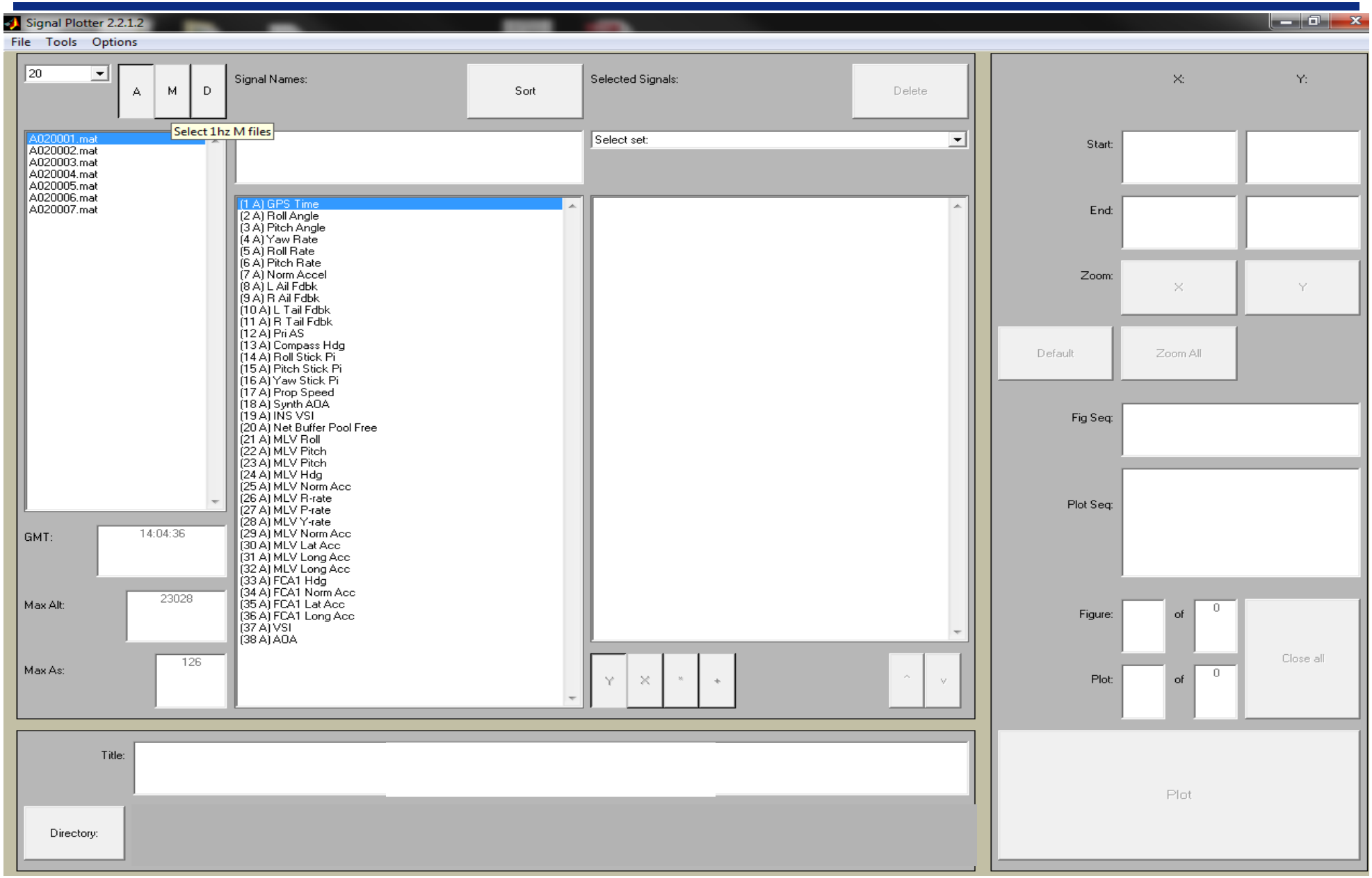
Dataloggers



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Dataloggers

- The M Files. Data which is recorded at 1Hz. Usually consists of temperatures, pressures and other parameters that may not require higher sampling rates (Note: some of the “A” file parameters are included in this list)
- Some examples:
  - Turbo Charger Oil Temp
  - Engine Oil Temp
  - Oil Pressure
  - Latitude
  - Longitude
  - Control surface feedback
  - Electrical parameters
  - Auto Pilot Quality

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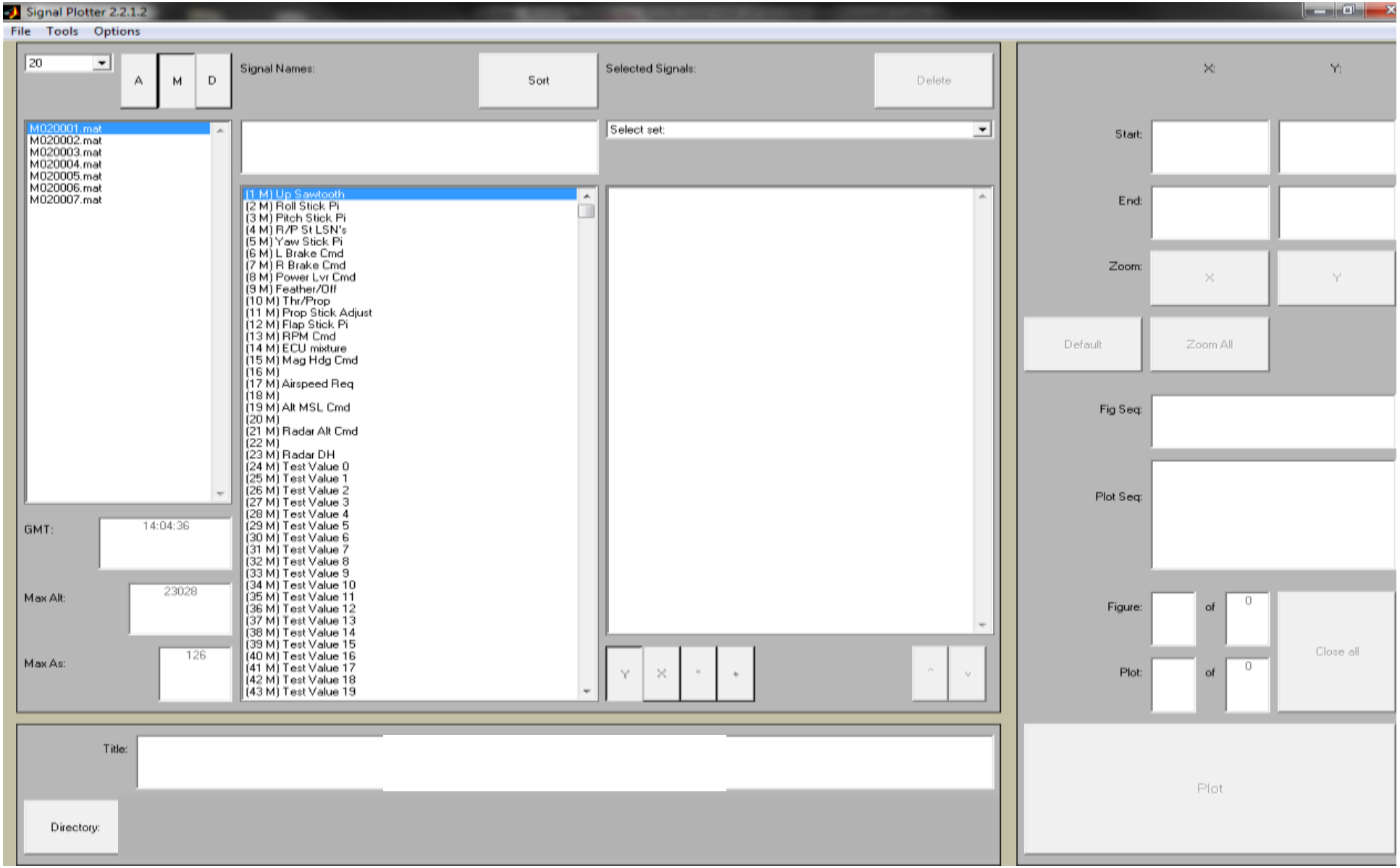
Investigation

MQ-1/MQ-9 Dataloggers



Dataloggers

- The D Files. Discrete data. Data which shows a discrete change in state from a zero to one, (or two or three). Recorded at 1Hz.
- Some examples
  - Landing gear Up or Down command
  - Cooling fan On or Off
  - Pitot heat On or Off
  - Nav Lights On or Off

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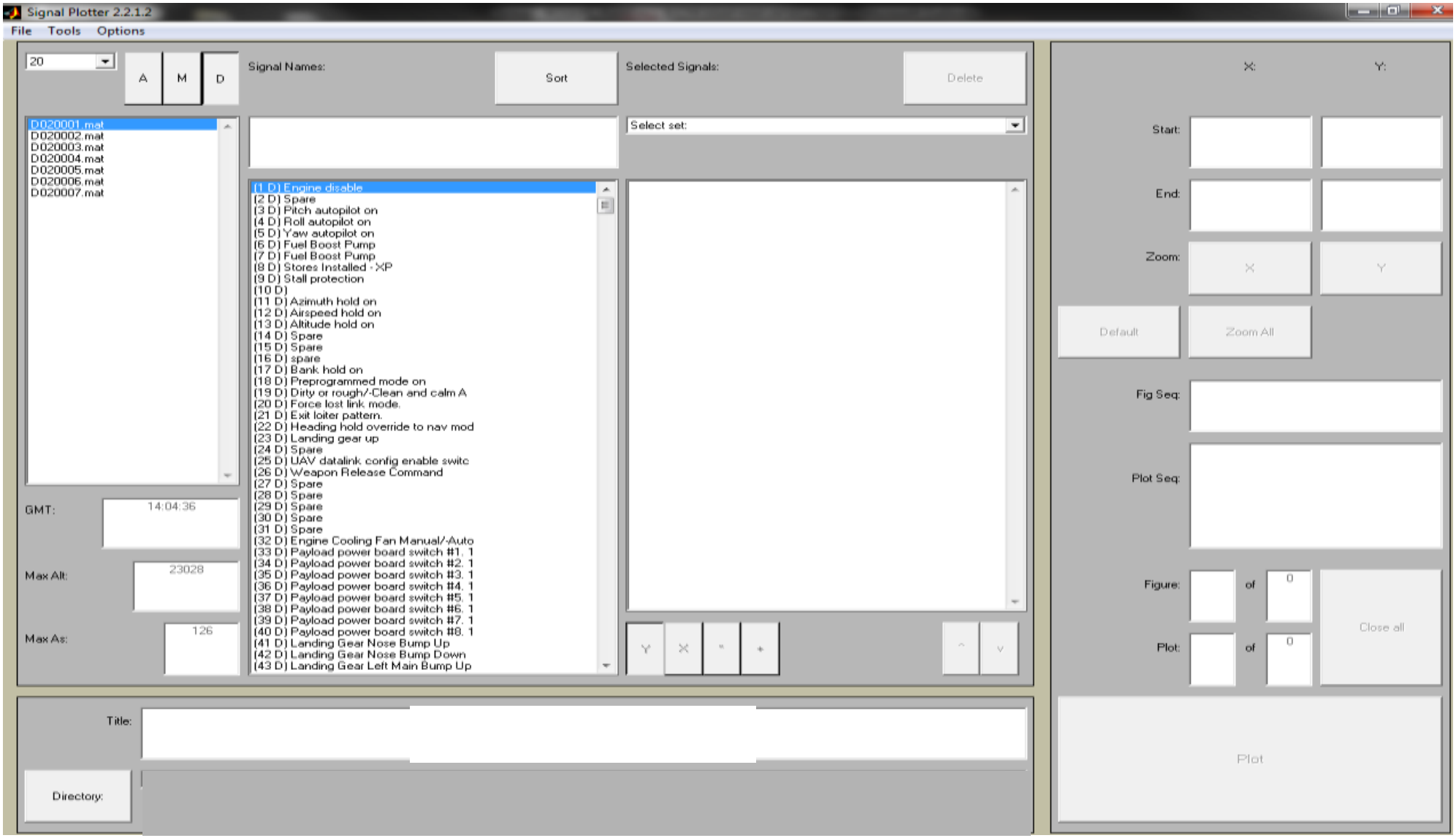
Investigation

MQ-1/MQ-9 Dataloggers



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Video Sources

- Next to the dataloggers, the videos are the second most valuable tool to the MQ-1/MQ-9 Investigator
- OCONUS videos are usually classified
- Depending on pilot selections they may or may not have HUD overlays.
- May also have audio of pilot/sensor interaction and ATC

Nose Cameras

- Nose Cameras
  - Fixed Position
  - Day TV or IR
  - Heated lenses
  - Color video using a sensitive charge-coupled device sensor array
  - HUD Overlays

Video Sources

- **Multi Spectral Targeting System (MTS Ball)**
  - **Day TV or IR**
  - **360 degree swivel**
  - **IR spot light**
  - **Laser designator**
  - **LLTV (low light TV) and "Fusion“ capability with IR**
  - **Multi Zoom Capable**
  - **Gyro stabilized**
  - **HUD overlays**

MTS Ball

- Video transmitted in downlink and stored in GCS
  - Slewing allows crew to look at wings, tail and gear position
  - IR can look for hot liquids (oil/coolant leaks)
  - IR can also easily see ice accumulation
  - In flight view of missing parts, vibrations, fire, leaks etc.

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Investigation - Wreckage

- Wreckage Shipment
- Lack of Wreckage
- Intentional Crash/Destruction of Wreckage
- Contamination/Looting of Wreckage
- Hostile Environment

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Challenges

- RPA mishaps pose many challenges to the investigator
  - There are usually several different crews involved in one mishap
  - These crews (maintenance and Ops) are in geographically diverse areas
  - The SIB boards are often inexperienced and difficult to man
  - The data we do have is often classified and we don't have data during lost link periods
  - Wreckage is sometimes never found, destroyed or looted
  - The Human Factors issues with RPAs are usually abundant and difficult to determine in the timeframe allowed in an investigation

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CASE #1

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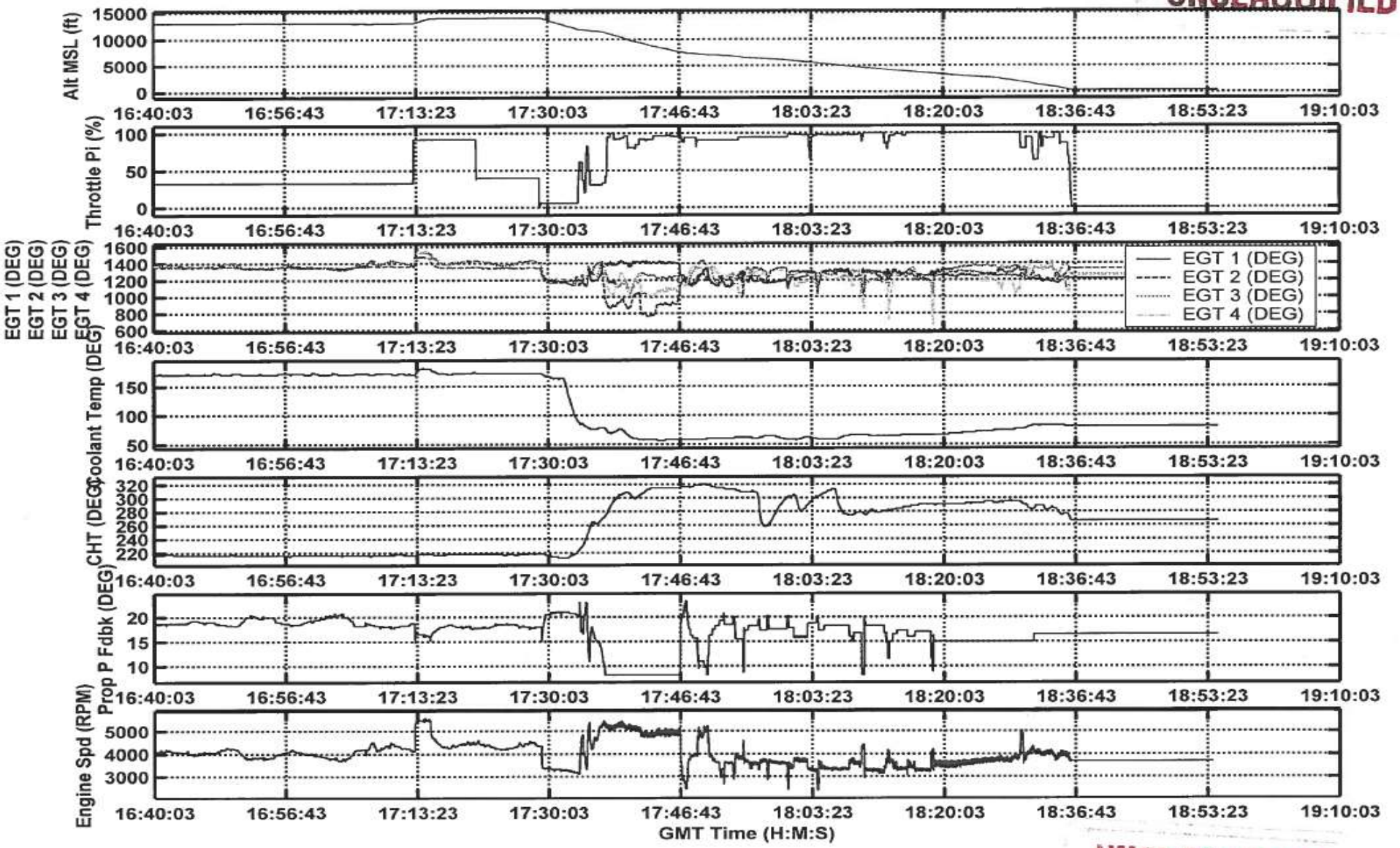
What was that?

Coolant Loss

UNCLASSIFIED



UNCLASSIFIED

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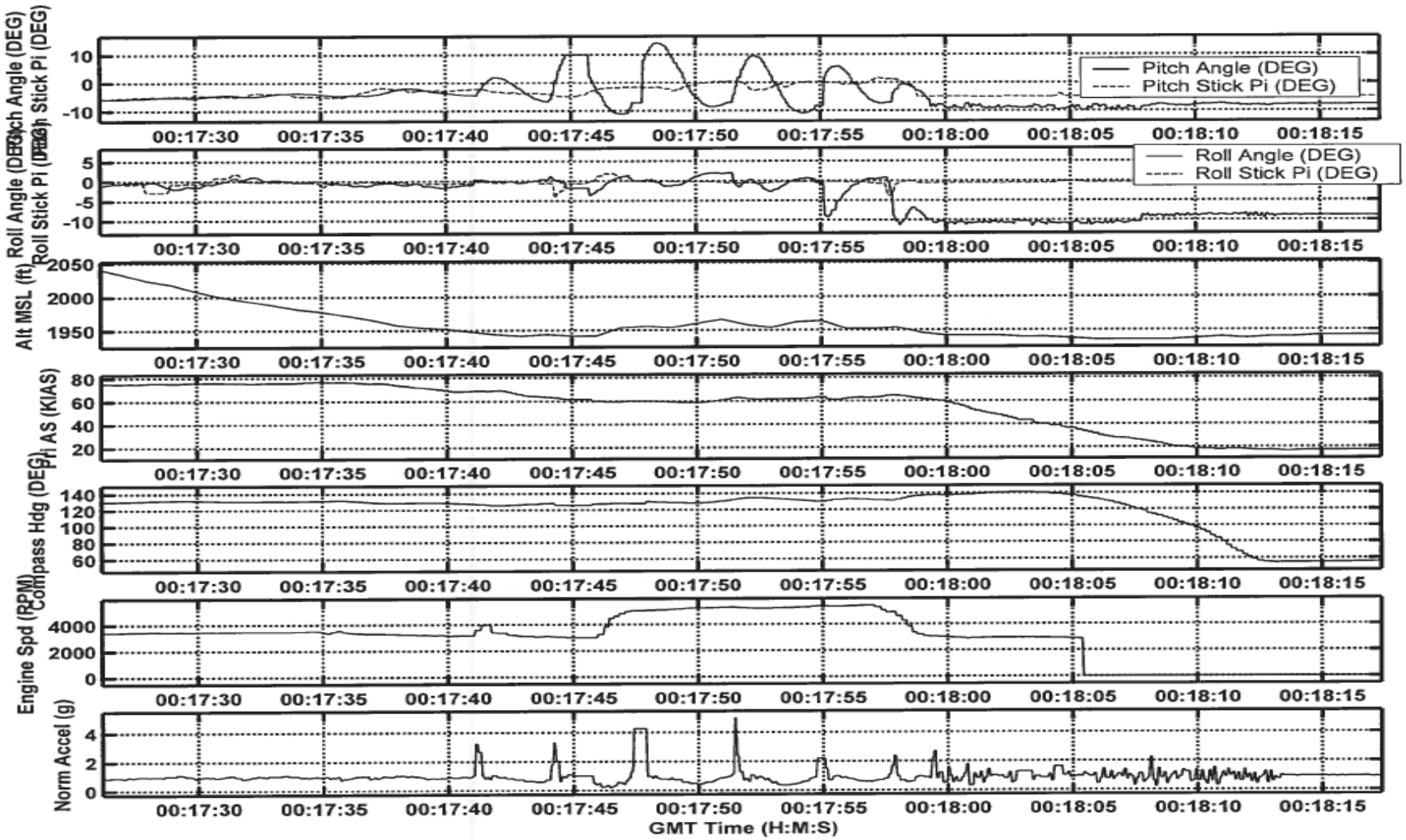
CASE #2

Hard Landing

Hard Landing

Unclassified



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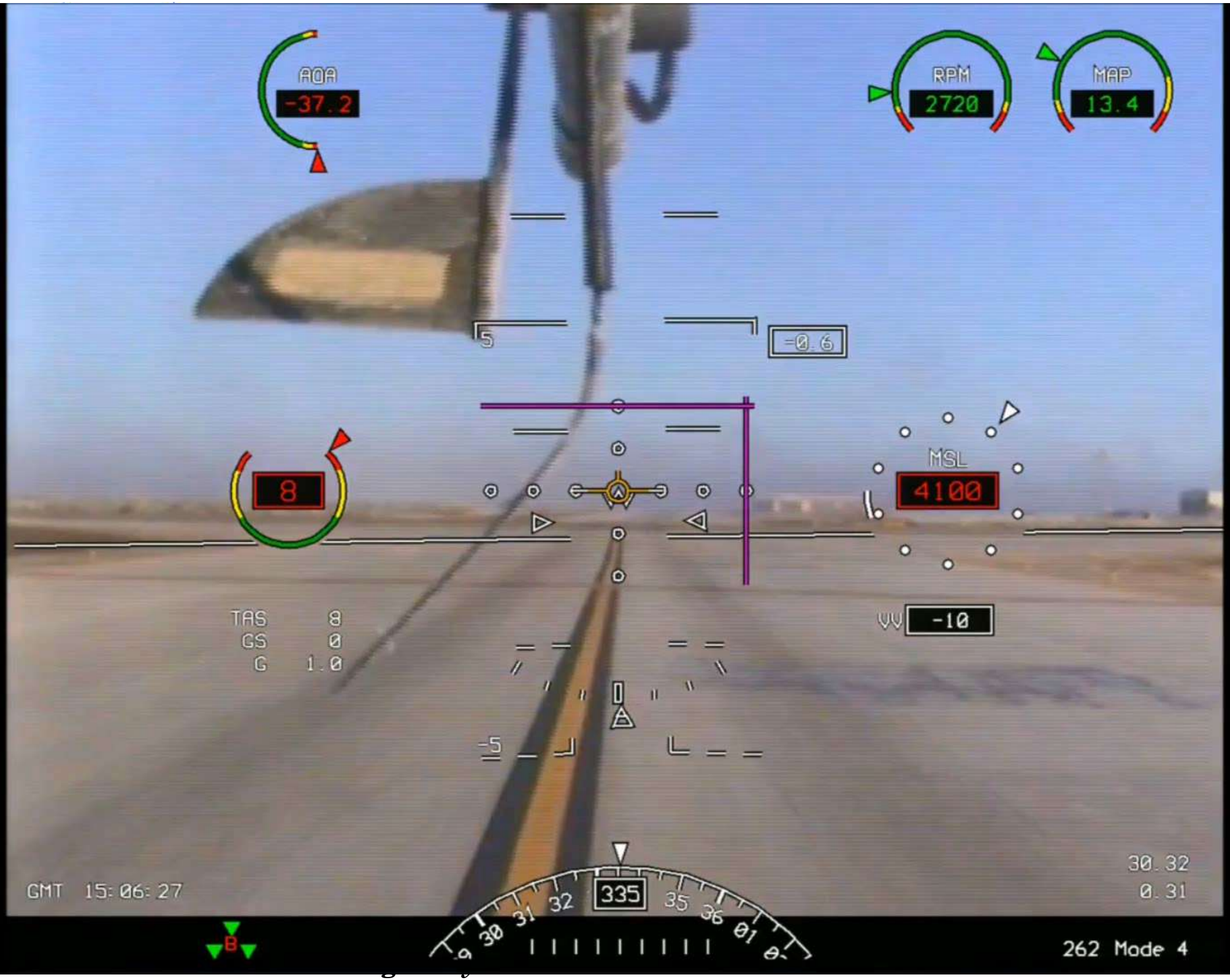
CASE #3


AOA
-37.2
RPM
2720
MAP
13.4
5
-0.6
8
MSL
4100
TAS 8
GS 0
G 1.0
VV
-10
-5
GMT 15:06:27
30.32
0.31
335
262 Made 4

AOA
2.8
RPM
5490
MAP
39.8
10
-2.3
77
MSL
4060
TAS 80
GS 78
G 1.0
-67
30.32
1.78
GMT 15:09:03
249
21 22 23 24 26 27 28 29
262 Mode 4

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Takeoff Incident

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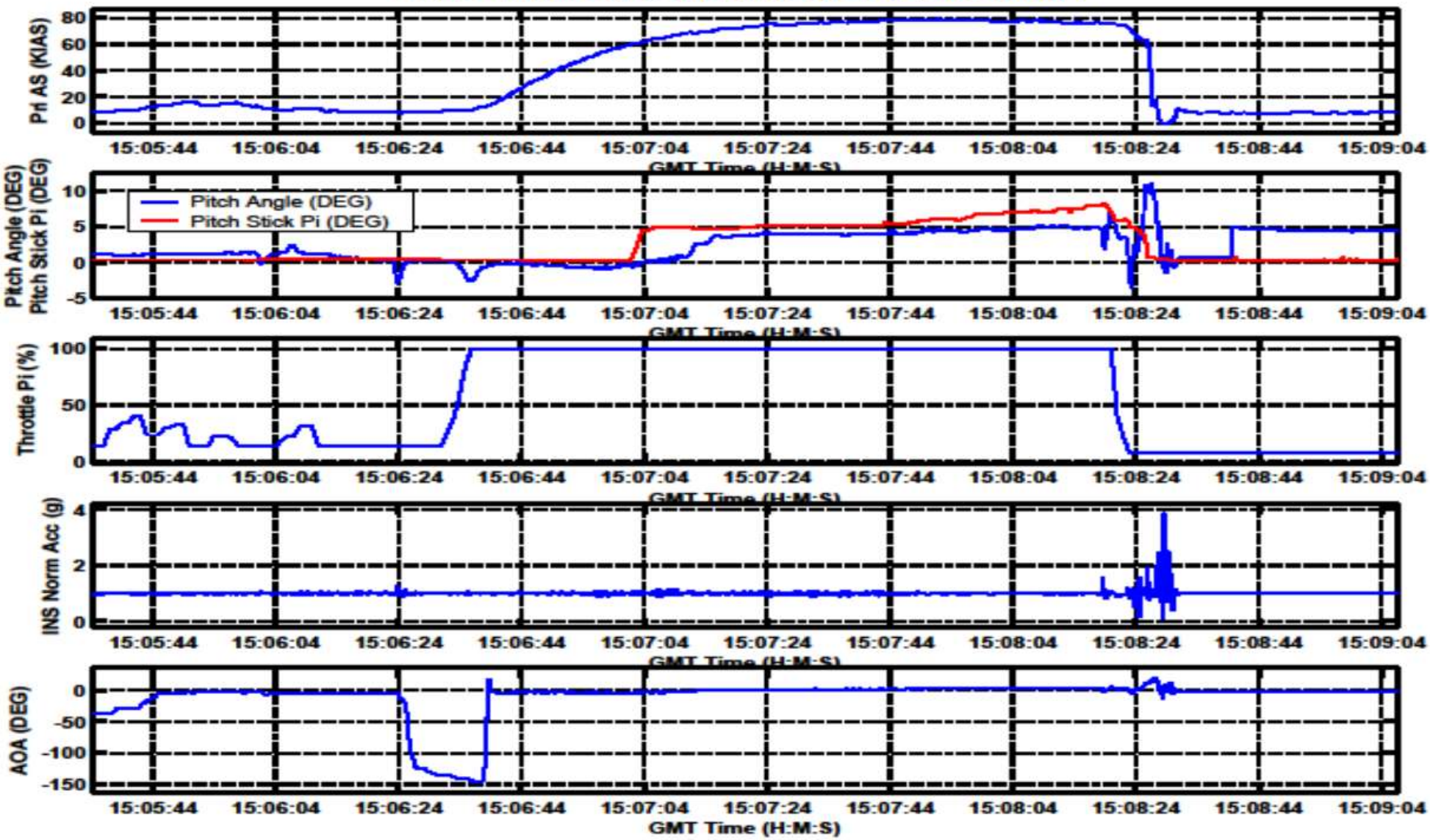
Takeoff Incident



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Takeoff Incident

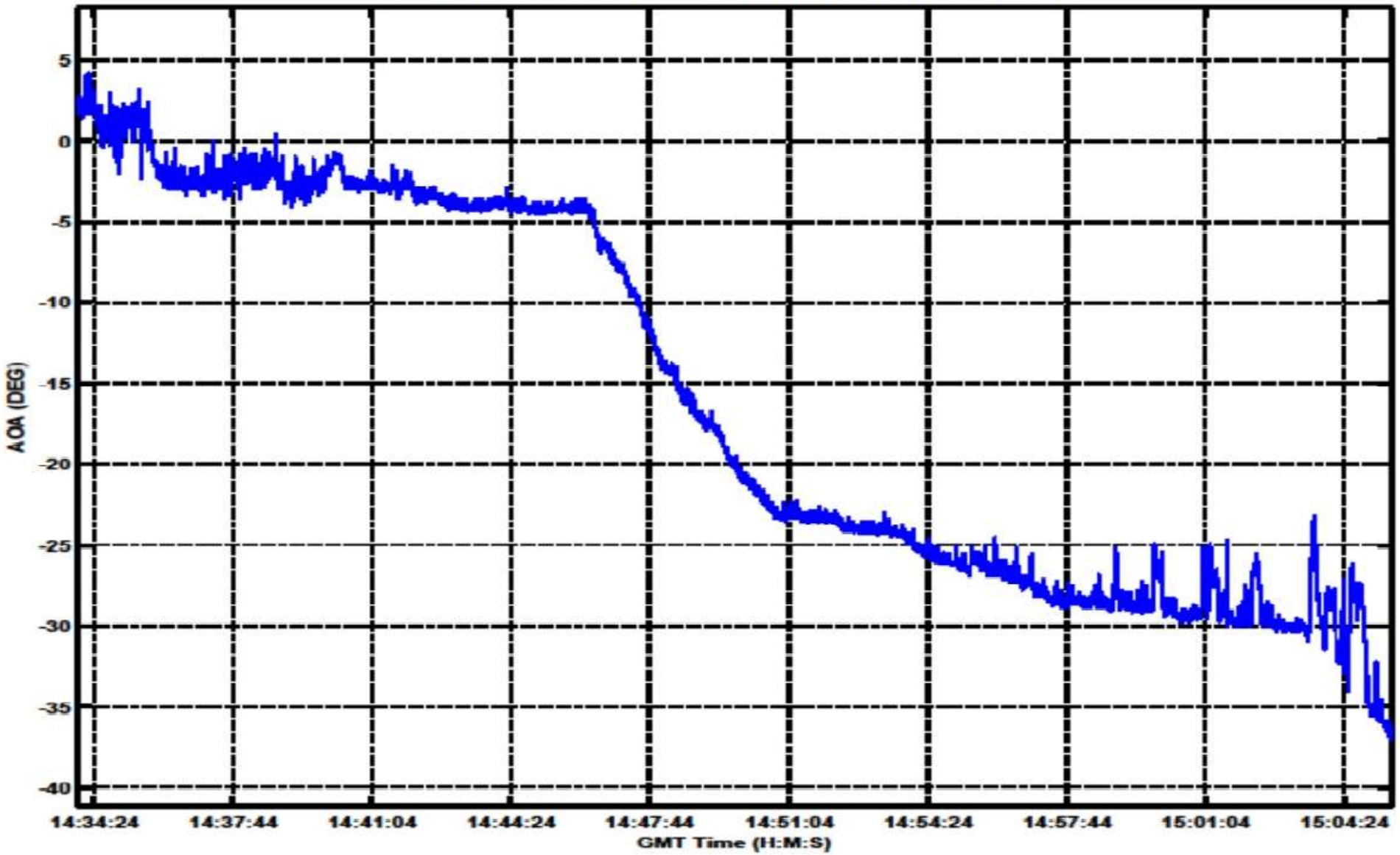
Takeoff Incident

Takeoff Incident

Takeoff Incident

Takeoff Incident

Takeoff Incident



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CASE #4

AOA
-1.1
RPM
3500
MAP
23.0
0.4
82
MSL
4500
TAS 98
GS 80
G 1.0
VV -467
-10
19:27:36
041
30.04
0.46
201 Mode 4

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Case # 4

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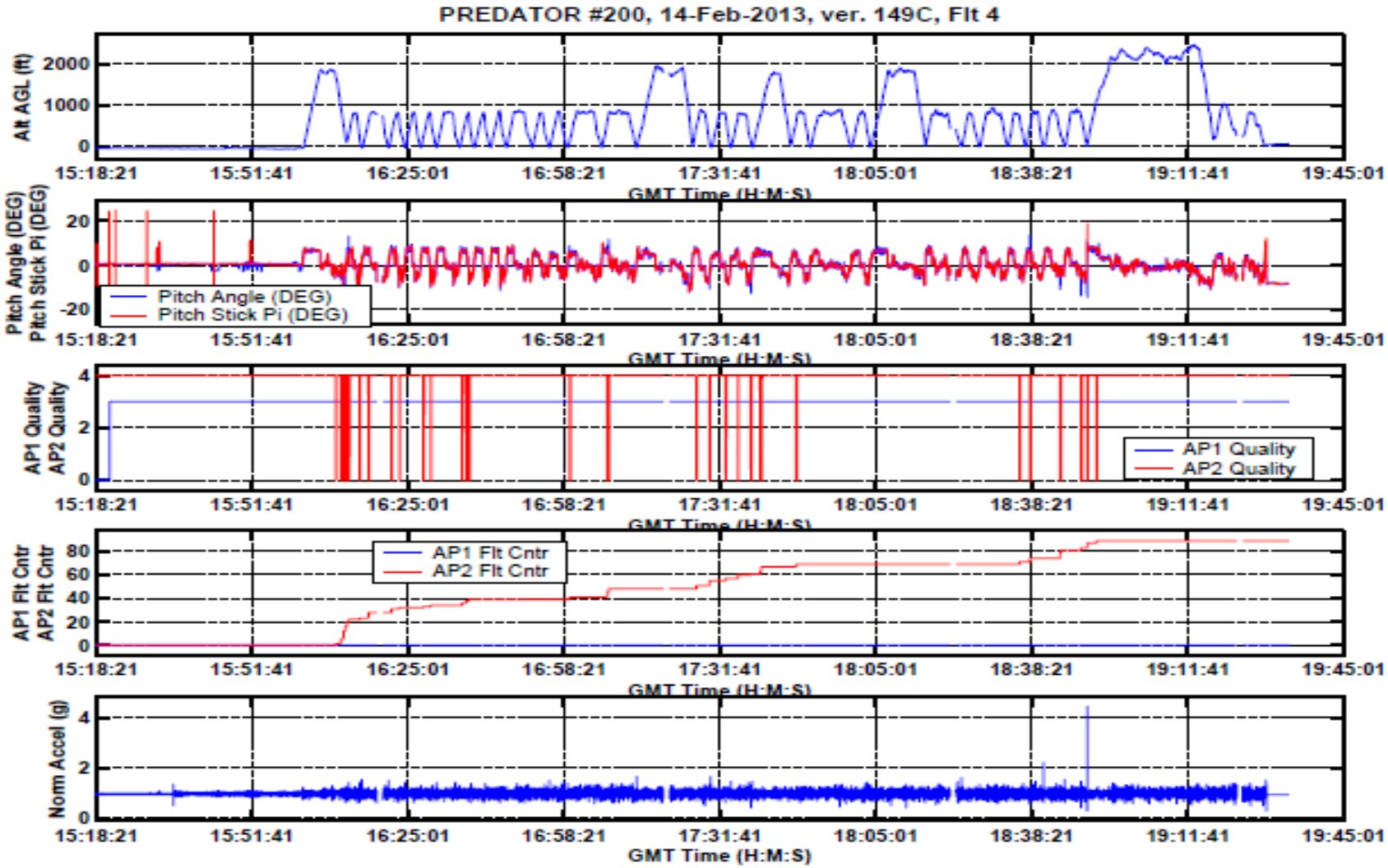
Case #2



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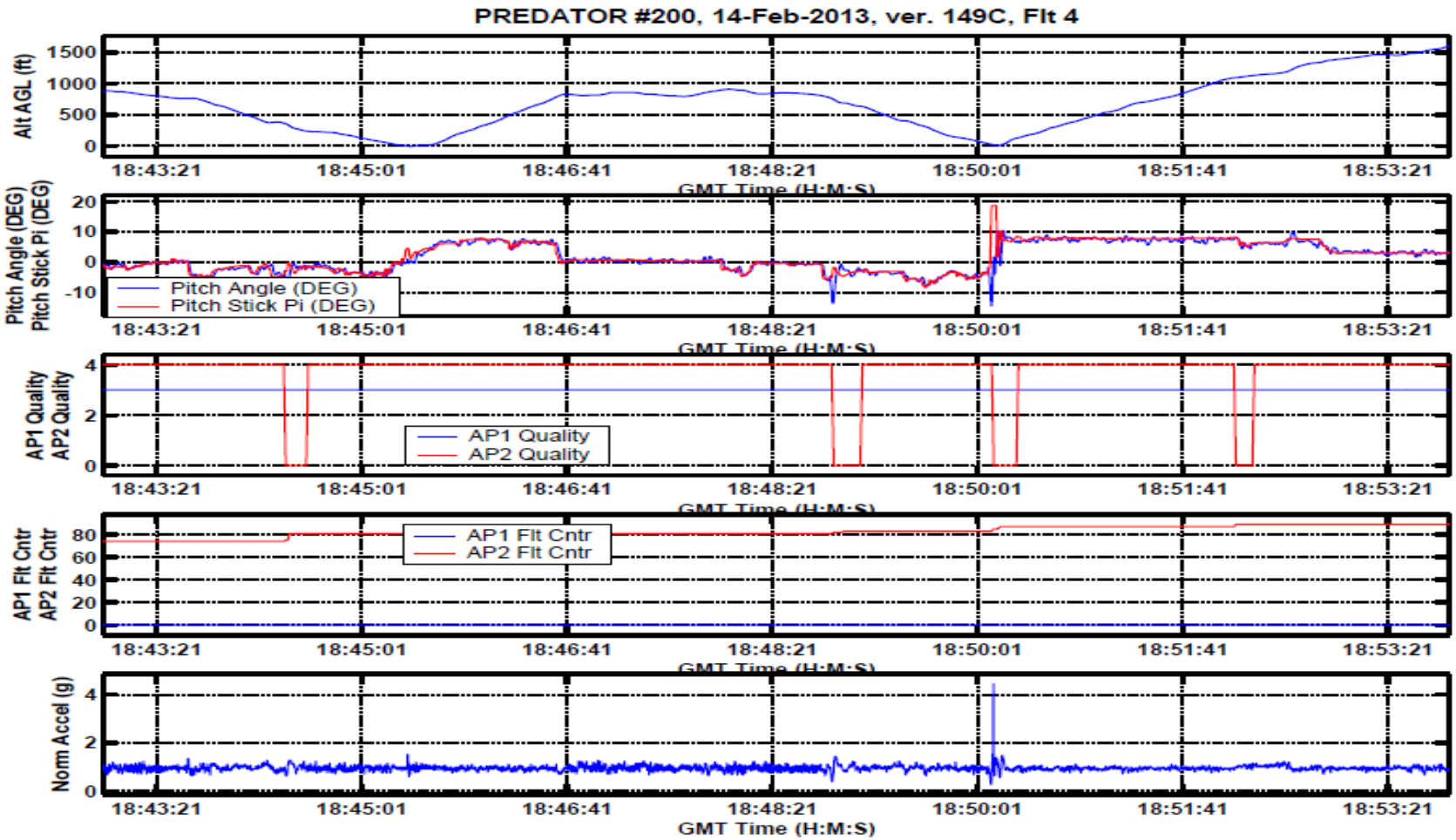
Case # 4



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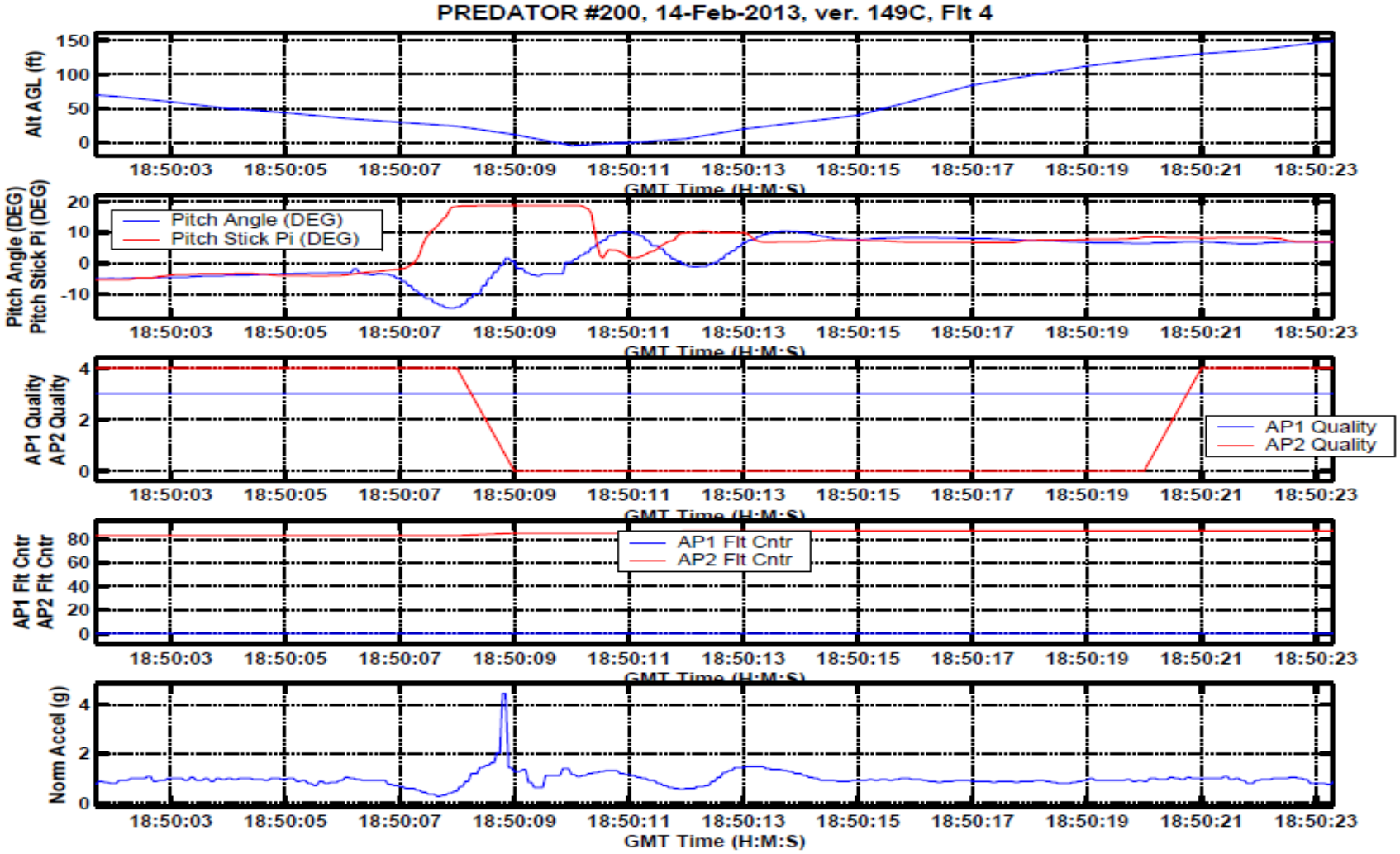
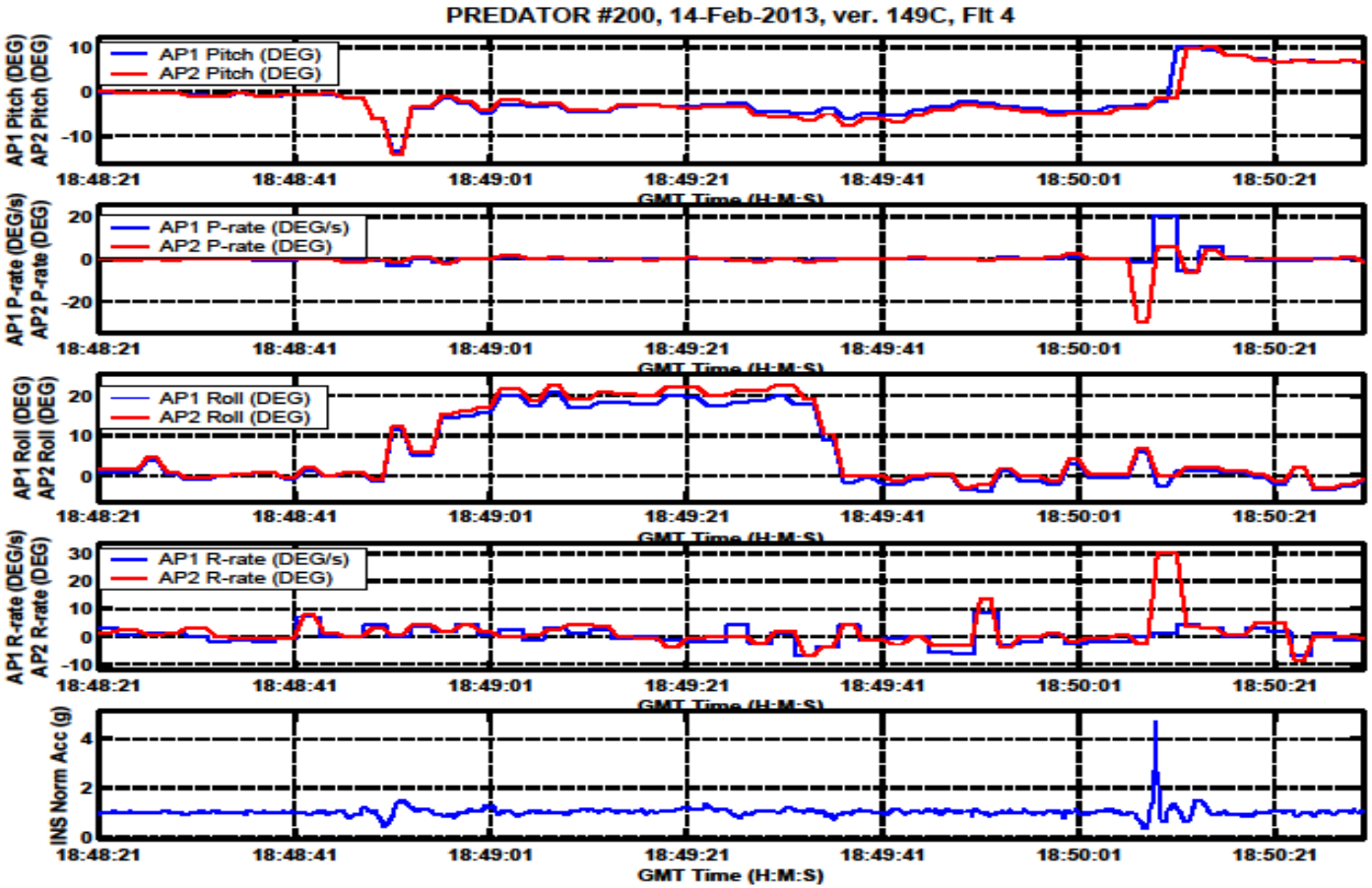
Case # 4



Case # 4


PREDATOR #200, 14-Feb-2013, ver. 149C, Flt 4
AP1 Pitch (DEG)
AP2 Pitch (DEG)
AP1 P-rate (DEG/s)
AP2 P-rate (DEG)
AP1 Roll (DEG)
AP2 Roll (DEG)
AP1 R-rate (DEG/s)
AP2 R-rate (DEG)
INS Norm Acc (g)
18:48:21
18:48:41
18:49:01
18:49:21
18:49:41
18:50:01
18:50:21
GMT Time (H:M:S)

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CASE #5

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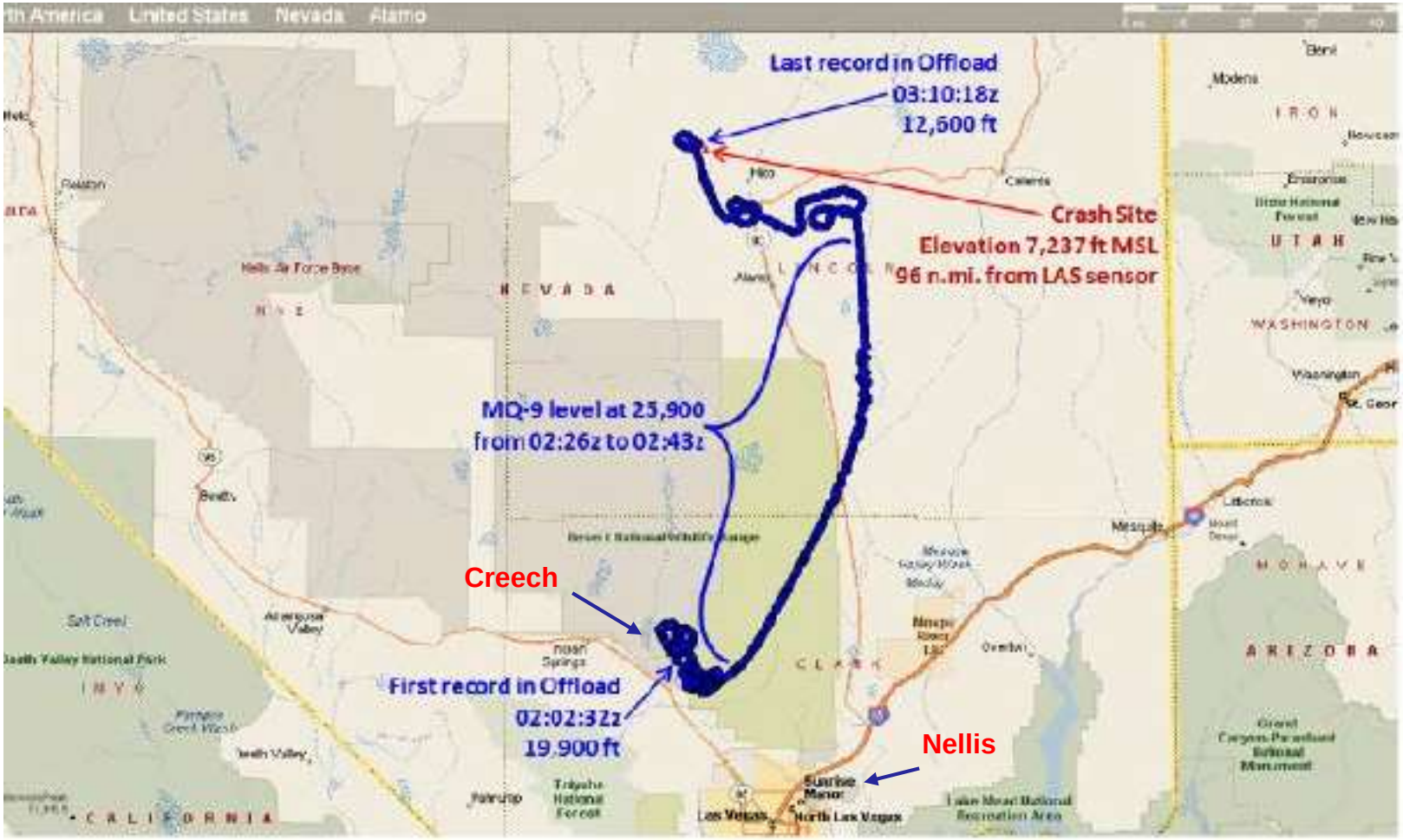
MQ-9 In Nellis NTTR

- MQ-9 on Weapons Training sortie in the Nellis Test and Training Range (NTTR).
  - Mishap Aircraft (MA) departed Creech AFB via C-band (line of sight) data link at 01:01Z under control of the Launch and Recovery Element (LRE) Ground Control Station (GCS) at Creech AFB.
  - After climbing to 19,900 ft the LRE handed the MA over to the Mission Control Element (MCE) crew who was operating their GCS out of Nellis AFB.
  - MCE crew picked up the MA via KU-band (satellite link) and climbed to 26,000 ft heading to the training area.
  - Due to weather, the package commander advised they would be going to a “Split War” scenario, which required the MA to descend to 12,000 ft and reposition to a different location.

MQ-9 In Nellis NTTR

- During the descent the MA performed an un-commanded pitch down maneuver and entered a high rate of descent which was undetected by the crew.
- After leveling off at 12,000 ft the MA performed a series of un-commanded pitch down maneuvers
- During troubleshooting of the flight control problem by the crew the MA pitched nose up, rolled left, departed controlled flight and lost link.
- The MA impacted the ground in a non-residential area at 03:10:30(Z), (1910:30 L), approximately 3 miles northeast of Mount Irish, Douglas County, NV.

MQ-9 In Nellis NTTR



MQ-9 In Nellis NTTR

MQ-9 In Nellis NTTR

MQ-9 In Nellis NTTR

- Video begins during the descent to 12,000 ft. MA is nose down 5 deg and in a slight left bank
- Altitude Hold is OFF Airspeed Hold is ON but turned OFF during the descent
- Airspeed is getting high at 142 Kts so the MP pulls the throttle back slightly from 100% to 96%
- The event occurs

161
-0.5
AOA
ULTW
BLK1
POS
1122
-5C
60
0
142
-10
N
LTHF
59.56
4316 Mode 4
CLK (GMT)
02:58:46
M36
M299
GBU38
GBU12
M299
M36

MQ-9 In Nellis NTTR

- Passing 13,000 ft the MP pulls nose up to -3 degrees to slow the descent
- Aileron “Tip Stall Override” appears on the HUD and the nose again drops to -15 degrees
- This was un-noticed by the Crew
- The pilot turns on Altitude Hold and sets it for 12,000 ft
- Aircraft resumes normal flight

233T
4.8
AOA
Aileron Tip Stall
Override
ULTW
BLK1
POS
1122
-4C
60
0
-120
83
97
12 390
7584 H
N
SEL
LTHF
59.69
4316 Mode 4
CLK (GMT)
03:02:07
M36
M299
GBU38
GBU12
M36
M299

MQ-9 In Nellis NTTR

- Aircraft is operating normally
- Crew is troubleshooting a “Closed Loop Power” Warning on the HUD
- First step is to turn Altitude Hold And Closed Loop Power OFF.
- When the MP does this the nose immediately drops to -15 Degrees
- MP notices the excursion
- MP turns Altitude Hold ON and goes to full power to climb to 12,000 ft

333T
ULTW
BLK1
POS
1122
-2C
60
0
-120
N
11 950
7529 H
80
SEL
LTHF
60.76
4316 Mode 4
CLK (GMT)
03:04:09
M36
M36
M299
GBU38
GBU12
M299

MQ-9 In Nellis NTTR

- Leveling at 12,000 ft the MP brings the throttle back
- The MA nose drops to -15 degrees
- MP performs “Loss of Control Prevent”
- MP Manually recovers the MA and uses full power to climb
- MP brings engine instruments up on the HUD
- MP levels MA off at 12,000 ft and reduces Power
- Nose drops -15 degrees
- MP Pulls back on the stick and adds Full Power

331 T
ULTW
BLK1
POS
1122
-1C
60
0
-120
N
5
5
89
11 650
5389 H
80
SEL
62.26
4316 Mode 4
CLK (GMT)
03:05:04
M36
M299
GBU38
GBU12
M36
M299

MQ-9 In Nellis NTTR

- Being distracted by a discussion with the Sensor operator, the MP did not notice the MA had climbed to 13,200 ft.
- The MP reduced power and pushed the nose over to -6 degrees
- Neglecting to trim to -6 degrees the nose returned to the previously selected trim setting of +3 degrees
- Un-noticed by the MP, the MA airspeed decayed and eventually the MA stalled, rolled left, lost link and crashed.

128T
1.3
100%
ULTW
BLK1
POS
KIAS
1122
0C
60
0
-120
134
84
SEL
LTHF
GS
Mode 4
CLK (GMT)
03:09:05
13 500
650
81%
TRQ
990
375
FUELF
N

MQ-9 In Nellis NTTR

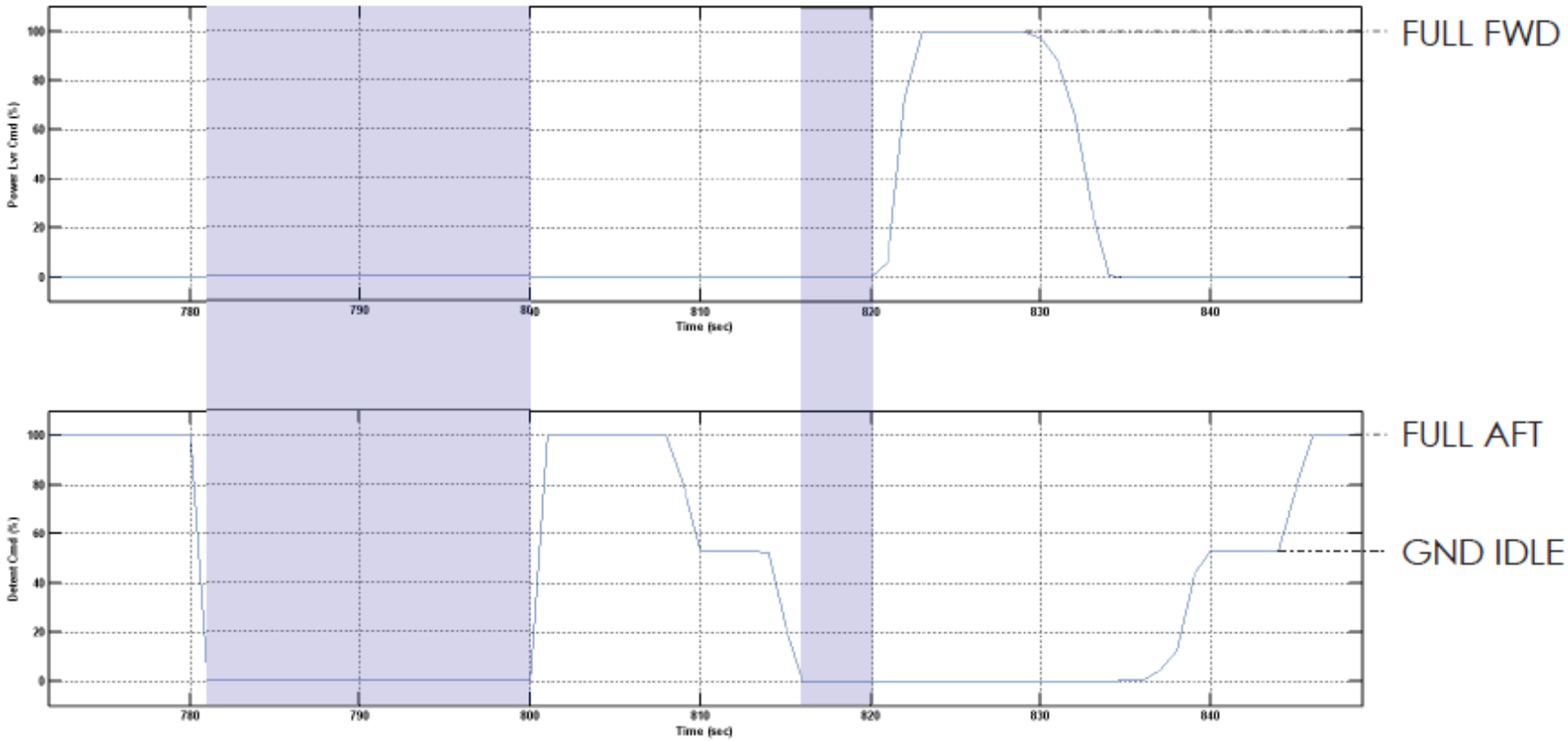
MQ-9 In Nellis NTTR

Power Lever at GND IDLE

Power Lever at FLT IDLE

MQ-9 In Nellis NTTR

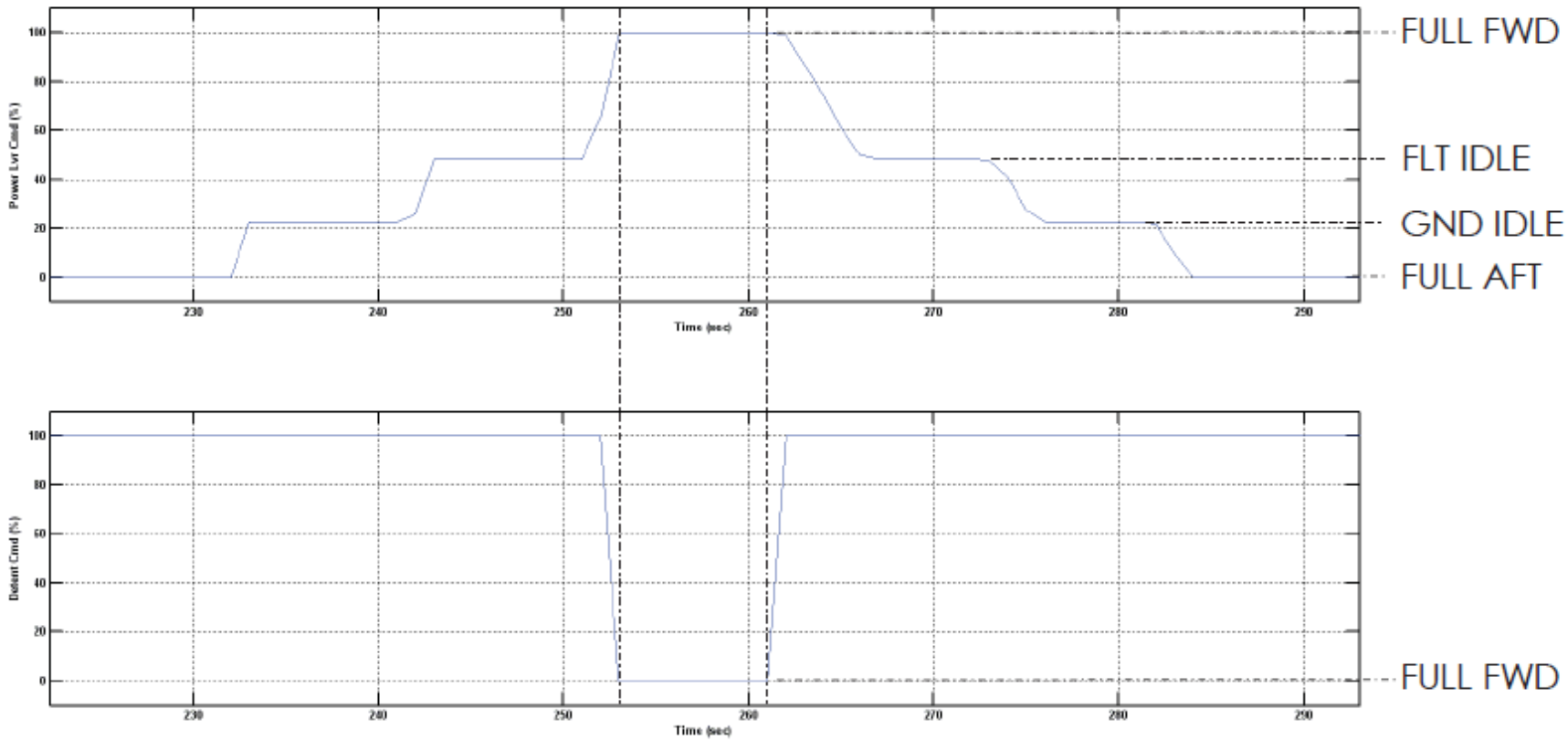
Calibration per the TO: Minimum Detent = FLT IDLE; Maximum Detent = FULL AFT



Purple Zones = FLT IDLE; PWR LVR CMD = DETENT CMD = 0%

MQ-9 In Nellis NTTR

Mishap Calibration: Minimum Detent = FULL AFT; Maximum Detent = FULL FWD



MQ-9 In Nellis NTTR

- Throttle in Nellis GSC was mis-calibrated by MX during change over from MQ-1 configuration and not caught by pilot who performed GCS setup.
- Mis-calibration resulted in 100% power when full forward, but full reverse at any setting below full forward.
- When operating in Altitude Hold mode the autopilot controls throttle correctly regardless of physical throttle position in GCS.
  - Each time throttle was reduced by MP or MP shut off Altitude Hold engine would go to full reverse.
- MCE pilots fly most of the time with hold modes on and do very little hand flying.
- MA was unaffected during LRE operations as the GCS at Creech was controlling.
- MA was unaffected after handoff to MCE until MP shut off Altitude Hold

Questions?