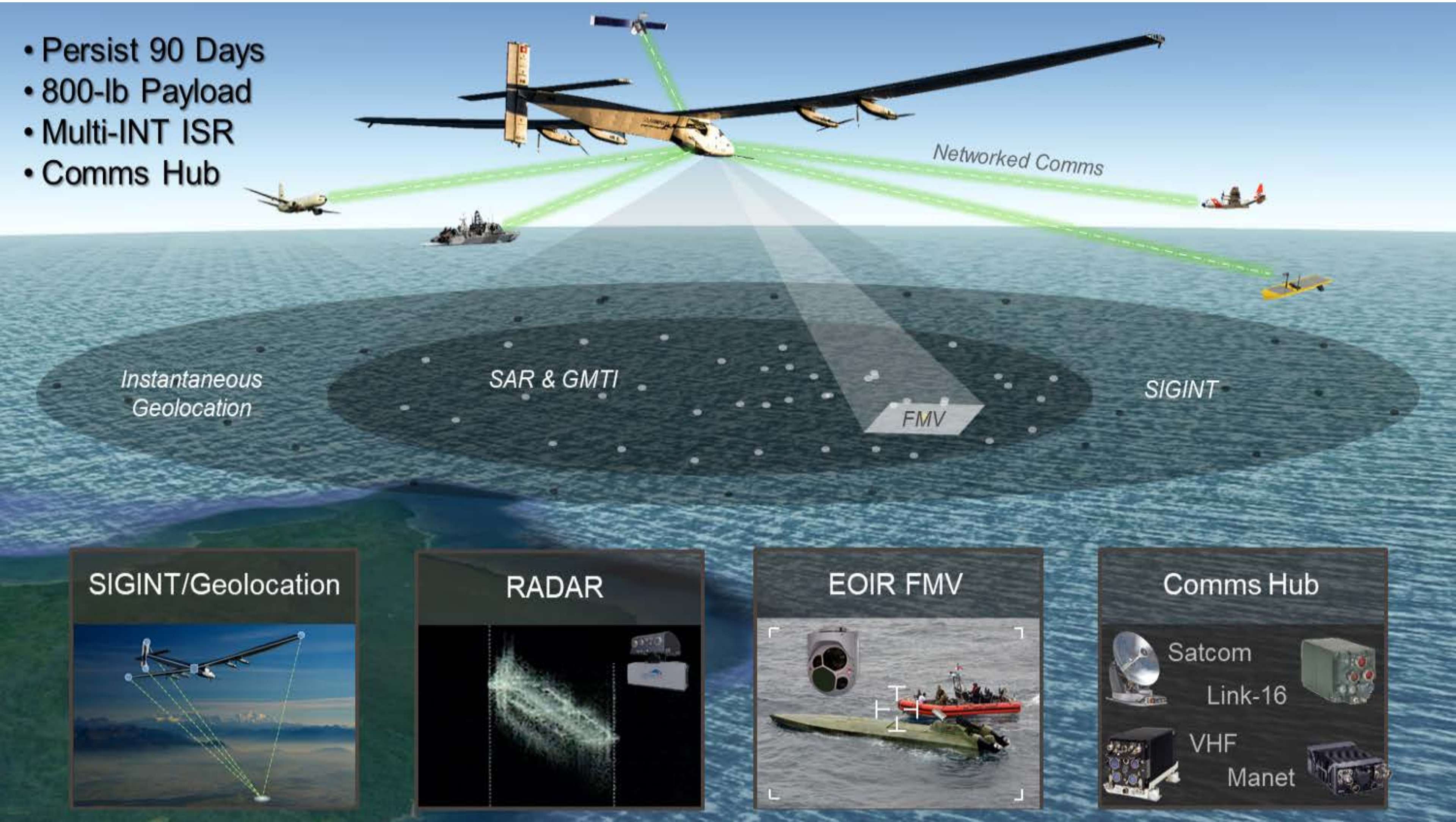
SKYDWELLER

Perpetual Flight™

Flight Demonstrations for Development of a Solar-Powered Unmanned Aircraft

Skydweller



• Persist 90 Days
• 800-lb Payload
• Multi-INT ISR
• Comms Hub
Networked Comms
Instantaneous Geolocation
SAR & GMTI
FMV
SIGINT
SIGINT/Geolocation
RADAR
EOIR FMV
Comms Hub
Satcom
Link-16
VHF
Manet

Dev Milestones

SKR
Return to Flight of SI-2

- Same configuration as SI-2
- Verify Health and Status
- Collect Flight Performance Data
- Permit to Fly from AESA
- Completed Dec 2020

AESA AGENCIA ESTATAL DE SEGURIDAD AÉREA

SKU1
Autonomy Demonstrator

- Permit to Fly from AESA
- Future actuation system
- Expanded envelope automatic flight control

AESA AGENCIA ESTATAL DE SEGURIDAD AÉREA

SKA
Pre-Series Production Prototype

- Optimized Airframe Structure
- New Production Airframe
- Military Airworthiness from DoD or European Defense Authority

INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL

Naval Air Systems Command (NAVAIR)

SPV
Safety Pilot Vehicle

- Automatic Flight Control with Onboard Backup Pilot
- Double Fail-Safe Flight Control System Interface
- Permit to Fly from AESA
- Completed Nov 2021

AESA AGENCIA ESTATAL DE SEGURIDAD AÉREA

SKU2
Unmanned Demonstrator

- Removal of Pilot and Avionics
- Redundant and fault tolerant flight control system
- Minimum airframe mods
- INTA Airworthiness Certificate

INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL

Naval Air Systems Command (NAVAIR)

Safety Piloted Vehicle

- **SPV allows reducing scope and design assurance**
- **Incremental approach to HW mods and SW features**
- **Flight functions are validated as available reducing risk**
  - Program cost and timeline saving

2020												2021												2022											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Return to Flight ✓ | **SPV Modification** ✓ | **SKU Modification**

1 | 2 | 3

HW
1. QMC – Improved Autopilot Computer
2. ARINC 429 to Ethernet converter
3. Serial to Ethernet Converter
4. GNSS – GPS antennae and receiver
5. INS – Inertial navigation system
6. Airborne Network Switch
7. Pilot interfaces (Display & Interface buttons)
8. DC/DC converter (PDDA)
9. Interface to SI2 motor drivers (APG)
10. LOS MANET Radio
11. Data acquisition
12. Data recorder

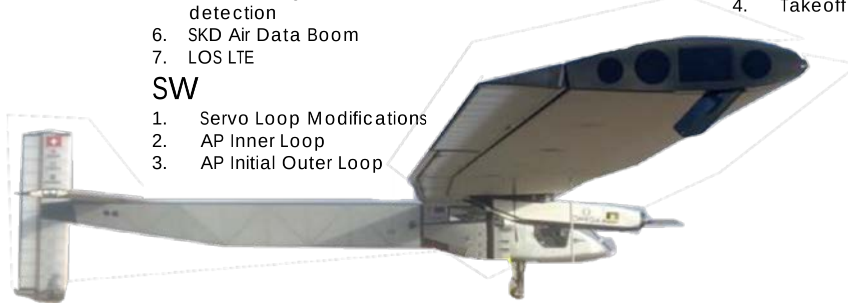
SW
1. Sensor integration
2. Servo Loop Closure
3. AP Architecture

HW
1. Laser Altimeter
2. VPN Router
3. Backup ADS
4. Wheel speed sensor
5. WoW – Weight on wheels detection
6. SKD Air Data Boom
7. LOS LTE

SW
1. Servo Loop Modifications
2. AP Inner Loop
3. AP Initial Outer Loop

HW
1. Tail Camera
2. Inmarsat
3. Future VMC
4. Remove Arinc Converter

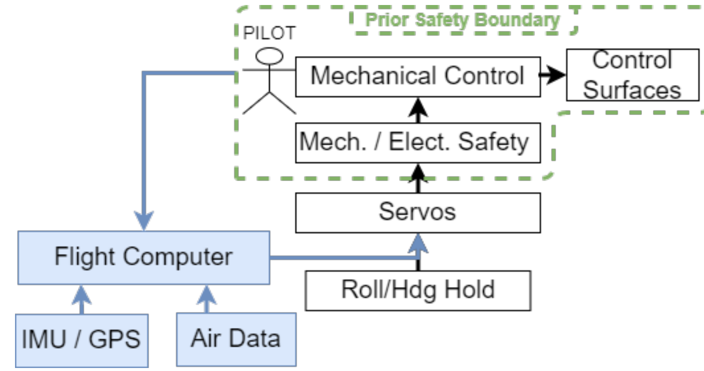
SW
1. AP Outer Loop
2. AP Guidance
3. Mission Plan Mgmt
4. Takeoff and Landing logic



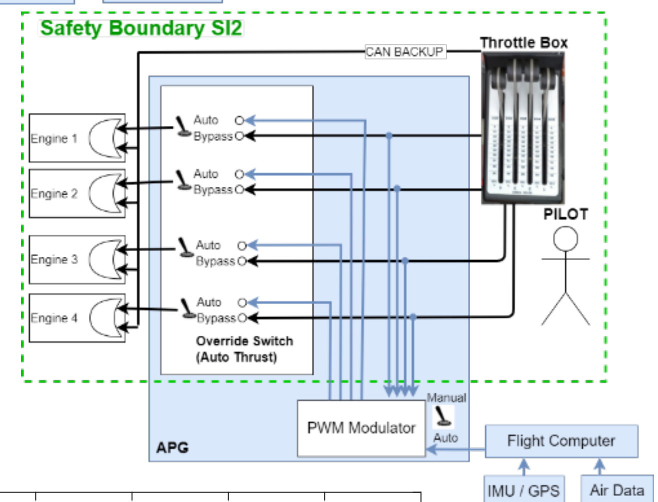
Flight Test

- **Flight Test as part of the engineering organization**
  - Involved in early System Design and Testing
  - Direct engineering support of flight test
- **Training**
  - Reused legacy SI2 Pilot training
  - Table-top, simulator, low and high speed taxiing
- **Decision making**
  - Coordination with weather for window selection, airspace use and extending the flight window
  - Coordination with engineering for flight test card selection
  - IP-based comms network to the airplane
- **Autonomous system interaction**
  - AP drives control chain and yoke with bumpless engage
  - AP increasingly used for airspace mgmt

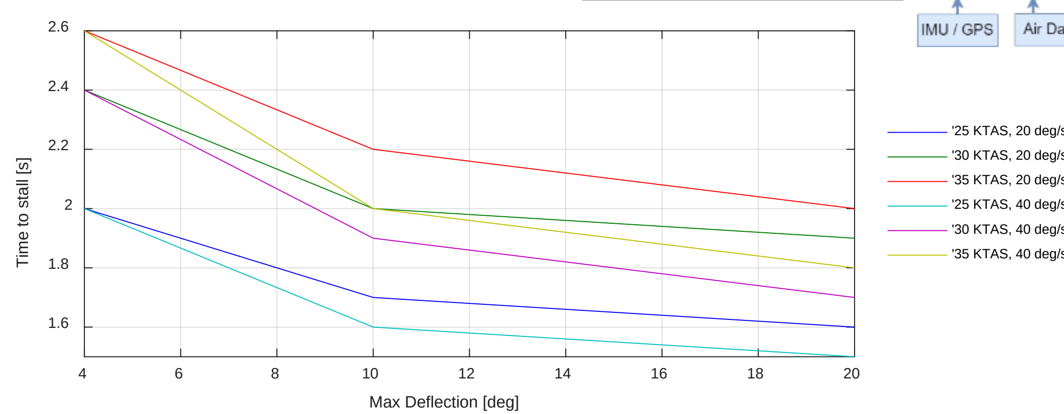
Safety & Airworthiness



- **Safety Boundaries:**
  - New functions are outside the safety boundary
  - Reused SI2 FCC as QMC
  - Surfaces reuse legacy SI2 safety boundary
  - Throttle used a custom developed APG

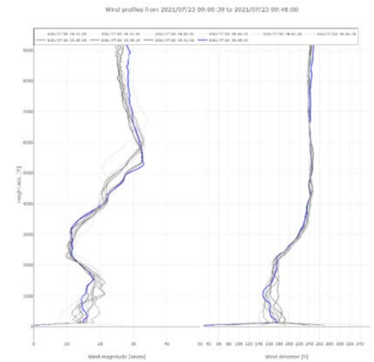


- **Pilot Response to Failures**
  - Pilot reaction time in case of hardover
  - Limiting case is stall speed severe limitation in elevator authority
- **PtFs**
  - Incremental PtFs
  - PtFs per HW mod

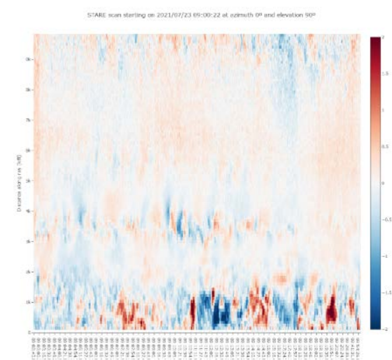


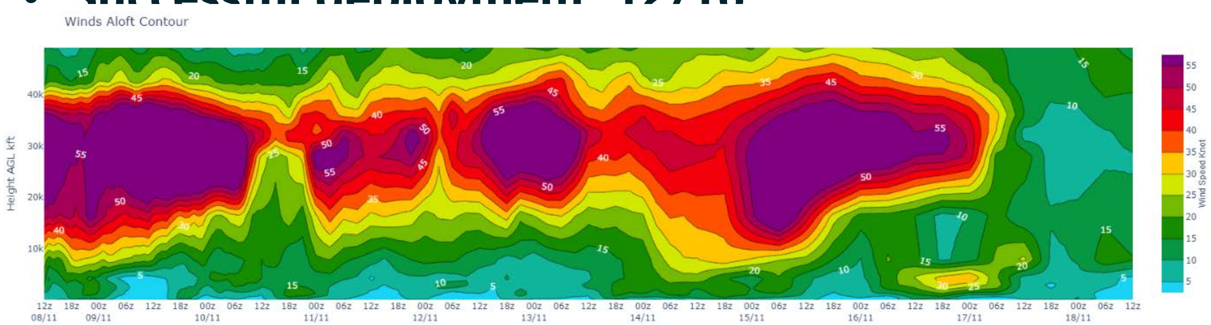
Weather

- **Challenges**
  - Wind and turbulence limits
  - Upper-level jets in the Albacete region and sparse data
- **Models**
  - Mesoscale models for thermals and gusts
  - LiDAR: monitor wind and vertical stability
  - Radiosonde for models above and correlation
  - Allowed capturing nocturnal jets and thermals missing in global models
- **Weather windows**
  - Summarized probability matrix: factors over time
- **Successful deployment: 12/16**



Winds Vertical Profile from LiDAR (Mag/Dir)

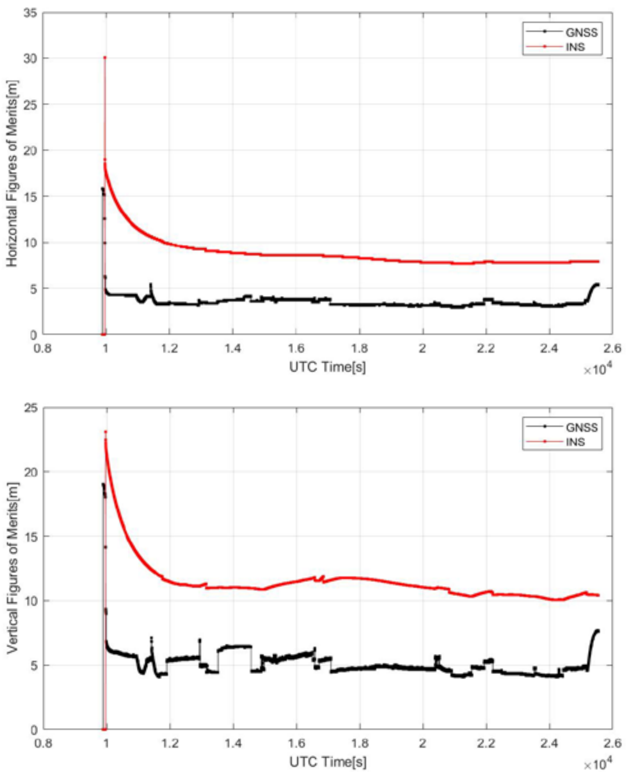




Upper-Level Winds Contour Plot

Navigation System

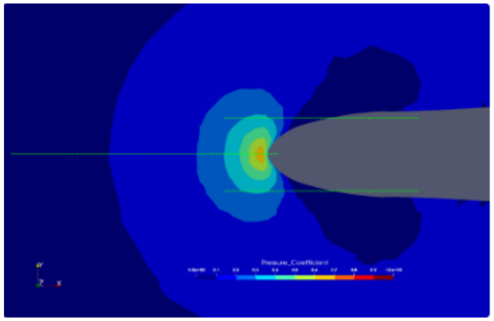
- **INS/GNSS integration**
  - Provides a tightly-coupled solution
- **GNSS Installation**
  - Good visibility, RAIM always active on INS and GNSS
- **INS installation**
  - Assessed location for auto flight performance
  - Verified location introduces no ASE issues
- **Successful in air-realignment of the INS**
  - Completed under low dynamic conditions
  - Readmit method increases availability needed to achieve 90-day flights (simpler than solution transfer methods)

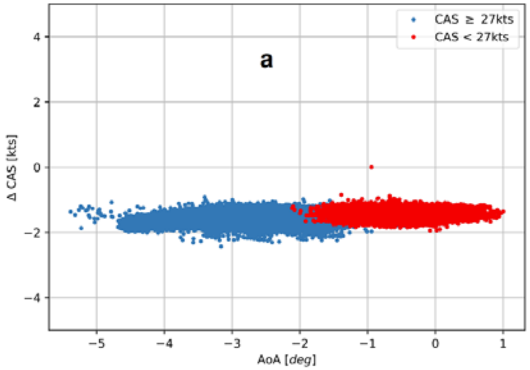


INS/GNSS
Horizontal and vertical FOM

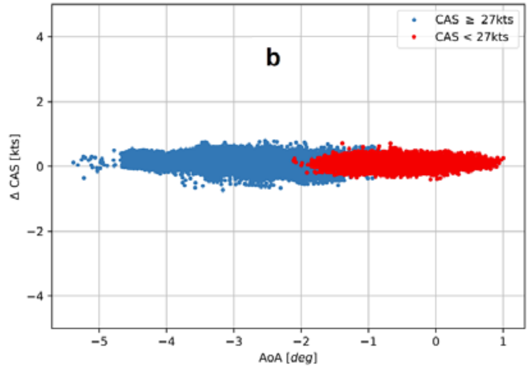
Air Data

- **Challenges**
  - Low speed: 15 kts at TO/LDG
  - High accuracy: ~2 kts diff b/w min power and stall
- **New ADS**
  - Multi-hole probe
  - Modular probe-ADC
- **Installation analyses**
  - Location chose to smooth correction changes
  - Traded with mechanical performance and safety
  - Installation errors corrected based on angles
- **Incremental updates**
  - Extended calibration data as necessary
- **System ready for unmanned flight**



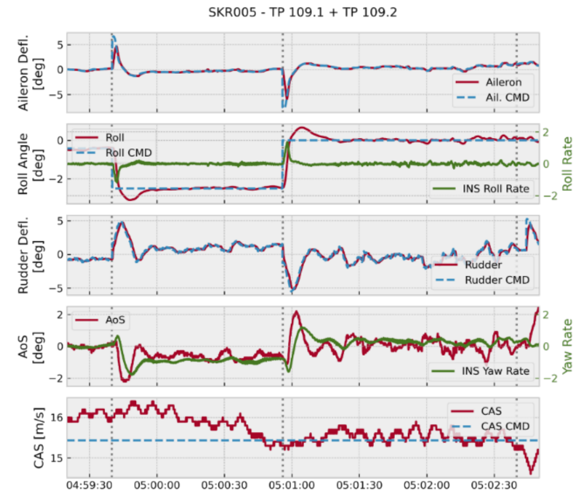


New ADS vs SI2 ADS Data:
- uncorrected (above)
- corrected (below)

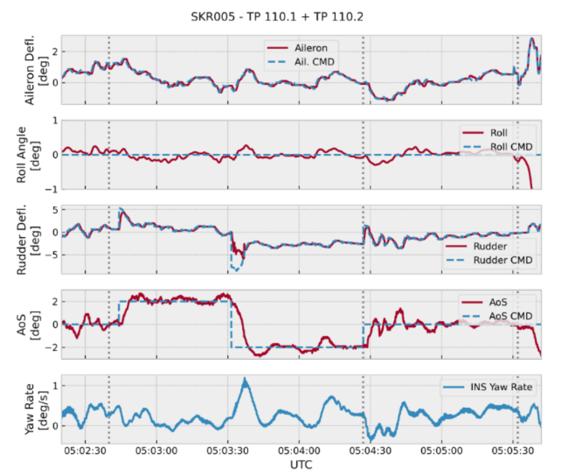


Flight Control

- **Challenges**
  - High airspeed accuracy with efficient control action
  - Size to speed ratio requires corrections ~~$(u_{\infty} \gg r \cdot b)$~~
  - Longitudinal modes: fast due to low wing loading
  - Lateral modes: adverse yaw, control coupling and little authority
- **Fast Flight Controls progression**
  - May: loop servo closure
  - July: attitude, airspeed and climb rate, initial track holding
  - Sep: initial VNAV/LNAV waypoint nav, high wind protections
  - Nov: complete waypoint nav, elevated approach, takeoff/landing shadowing
- **Incremental improvements**
  - Servo loop closure to alleviate stiction
  - High wind protection to improve leg capture



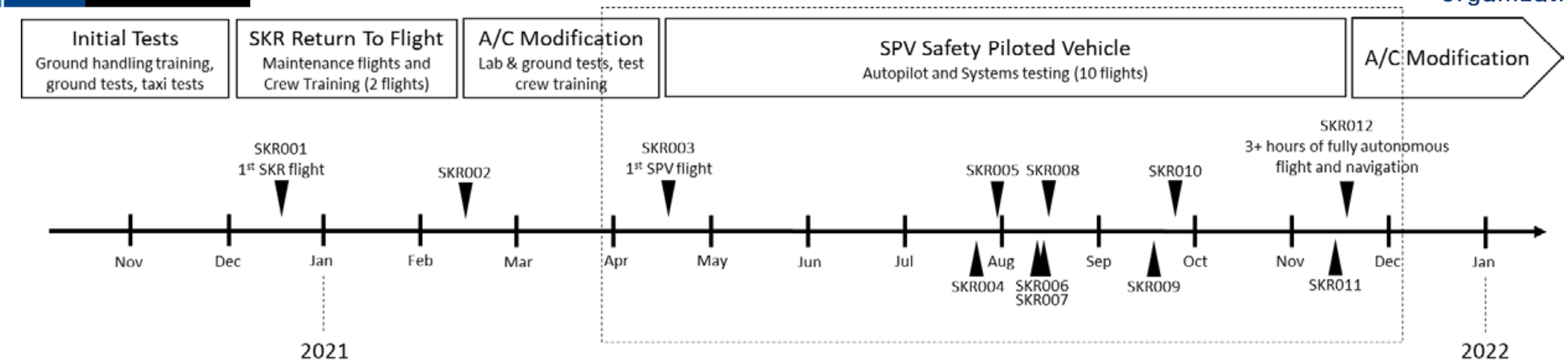
Roll and AOS step responses



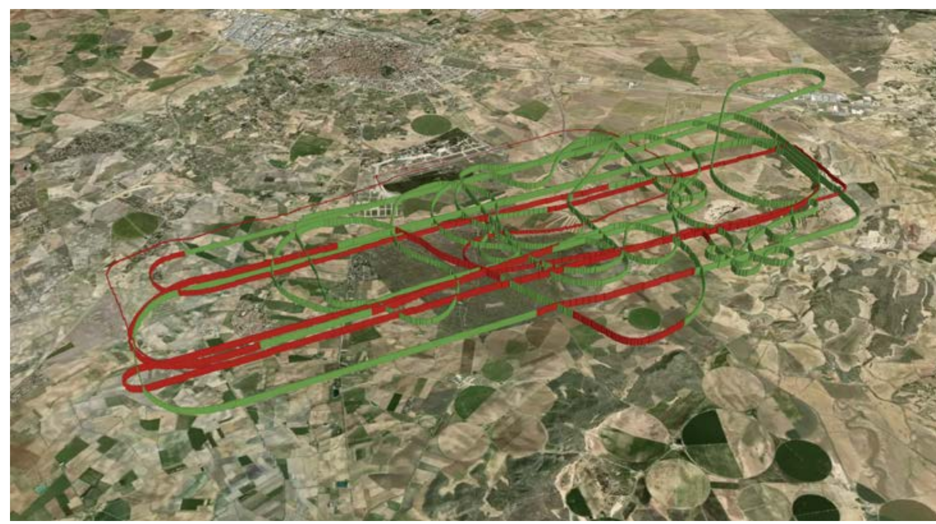
Flight Control

First Waypoint Navigation engagement

Progression of Flights



Flight	Description
SKR003	• AP engagement • INS in-flight alignment
SKR004	• Pilot training • Timing issues found in the QMC
SKR005	• Pilot training • Airspeed, altitude rate, roll and sideslip control
SKR006 SKR007	• Back-to-back flights • SysId maneuvers and disturbance rejection • Use of new Air Data Boom in closed loop
SKR008	• AP envelope clearance to 26 kts • AP Initial track holding demonstration
SKR009	• Tested autopilot with airbrake • AP use for airspace mgmt, 27 minutes in closed loop
SKR010	• Waypoint navigation with complete LNAV • Checked high wind protection logic • 113 minutes on closed loop
SKR011	• First flight with future VMC. Found SW issues. • Dynamics envelope clearance
SKR012	• AP envelope clearance: min speed, bank angle • AP configuration: airbrake and landing gear • Waypoint Navigation with complete VNAV • Elevated approach • Take-off and landing logic shadowing • +3 hours of AP engagement, 5 hours



NATO OTAN

SKYDWELLER

Perpetual Flight™

S&T organization

Thank you