

# Spanwise Adaptive Wing – PTERA Flight Test

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# PTERA Overview

Prototype-Technology Evaluation Research Aircraft (PTERA): “A flying laboratory”



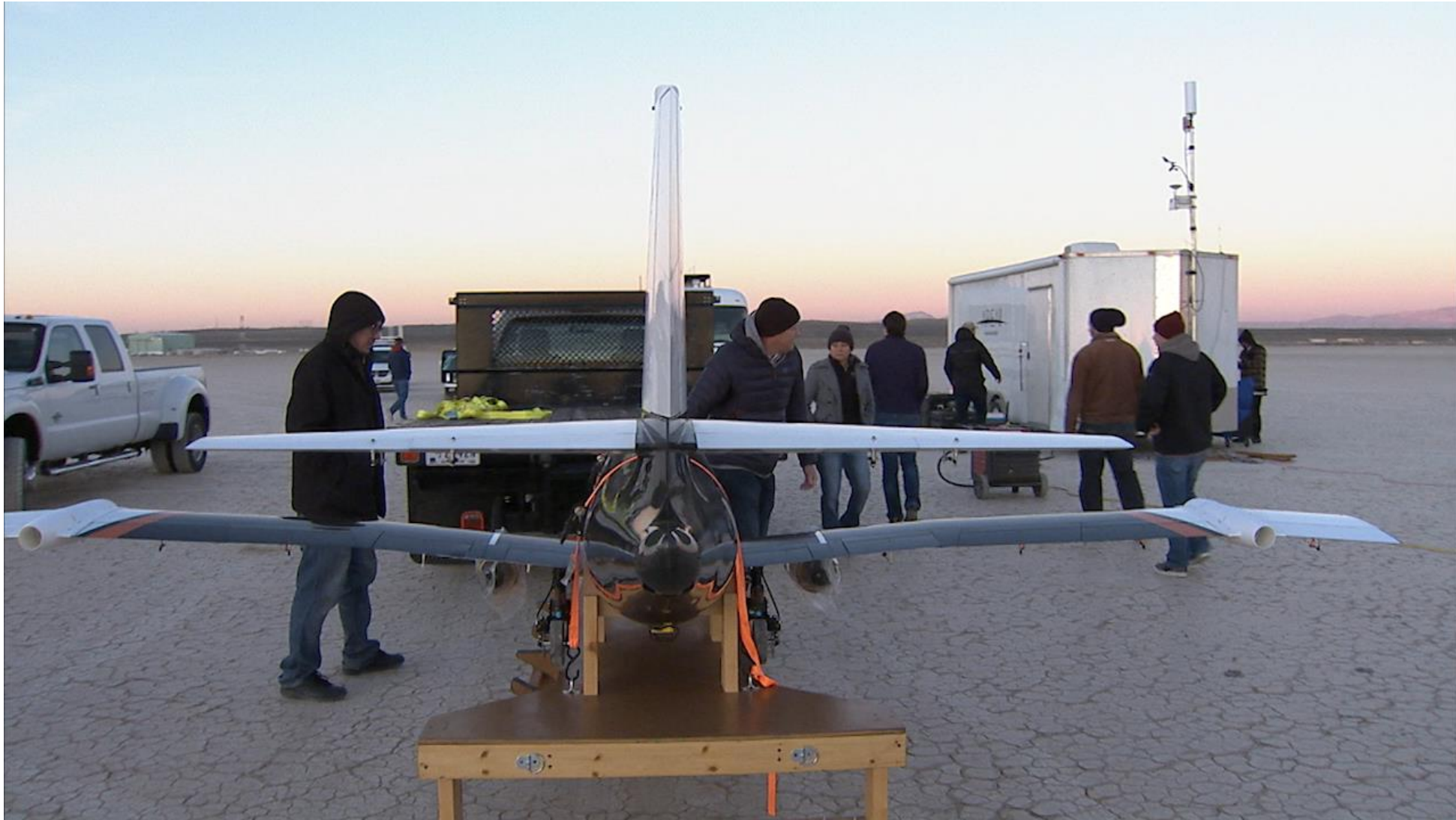
“ptera” is Greek for wing or wing like

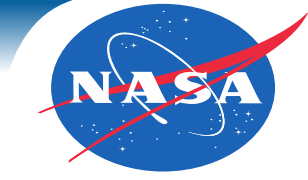
# PTERA Flight Test Architecture

- Area-I “Maestro” Flight Management System:
  - Primary PTERA autopilot and Ground Control System
    - Variable levels of autonomy; fully autonomous to manually piloted
  - Automated maneuvers for in-flight airframe system identification
    - Independent control and actuation up to 16 control surfaces
  - Readily modified to support guest payloads and guest control architecture:
    - Boeing SAW actuators (command and control, state, telemetry, etc.)
    - NASA ARTS flight control system
  - Highly instrumented for real-time aircraft state and health monitoring:
    - Dual-GPS INS (minimizes heading error)
    - 5-hole pitot tube (angle of attack and sideslip)
    - Control surface deflections, battery, and engine states
    - Recorded onboard at 50-100Hz, telemetry to GCS at 10Hz
  - Redundancy:
    - Dual independent flight-control power systems
    - Cloud Cap Piccolo II autopilot and GCS (backup flight control and INS)
    - Dual onboard receivers for external pilot



# PTERA Flight Test Video





# Flight Test Goal and Objectives

- Fold the PTERA wings in flight with integrated self-contained SMA actuation
- Validate aircraft models in order to design control laws
- Assess aircraft aerodynamic performance
- Validate NiTiHf SMA material
- Vet system integration



# Approach

- Priority to fold the PTERA wings in flight with SMA actuation to test the integrated self-contained SMA system
  - wing tip deflection from  $0^\circ$  to  $70^\circ$  range in both directions
- Specific test maneuvers flown to validate aircraft models
- Observed doublet test maneuvers to assess aircraft performance

# Great Work Team!



# Background

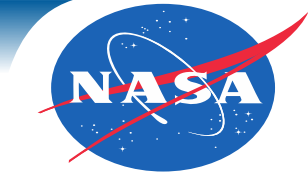
- Folding PTERA aircraft wings in flight using SMA actuators to increase yaw power and stability
- Flight operation being conducted by Area-I
  - Contracted via SBIR Phase 3
  - Flight conducted with Area-GCS and pilot
- NASA Responsible for:
  - Range Safety
  - Vehicle (NASA owned)
  - Mishap





# Control of PTERA

- External pilot completed takeoff and landing
- Most of the flight flown by the Onboard Tracker (Autopilot)
  - Commanded by GCSO (Ground Control Station Operator) in the AREA-I Ground Control Station (GCS)
- External pilot, Internal pilot (GCSO with Joystick in GCS) and Piccolo are backups for the GCSO during mission
- No chase vehicle for flight tests



# PTERA Flight Test Conditions

- All test points to start at 3,300 ft MSL
- Test condition speeds: 70 kts, 90 kts, 110 kts
  - Test winglet settings of -70, -35, 0, 35 and 70 deg
- On condition:
  - Airspeed: +/- 5 kts
  - Wing tip position: +/-5°
  - Altitude: +/- 100 ft

# Flight 0

Date: Thursday December 14, 2017

Time: Approx. 5:00 pm

Purpose: Pilot familiarization, Piccolo Autopilot checkout, AREA-I Autopilot checkout, and wing tip folding in 15° increments up to 45° down

Duration: Flight scrubbed

Wing Tip Configuration: Rigged down, commanded to 0° for take off

Flight pattern: N/A flight scrubbed

Comments: Trouble shooting the COTS Jetcat turbine engines caused delays. By the time issues were resolved the sun was setting. External Pilot felt uncomfortable with the reduced visibility caused by the sun glare causing the Test Director to scrub.



# Flight 1

Date: Friday December 15, 2017

Time: Approx. 9:35 am

Purpose: Pilot familiarization, Piccolo Autopilot checkout, AREA-I Autopilot checkout, and wing tip folding in 15° increments up to 45 ° down

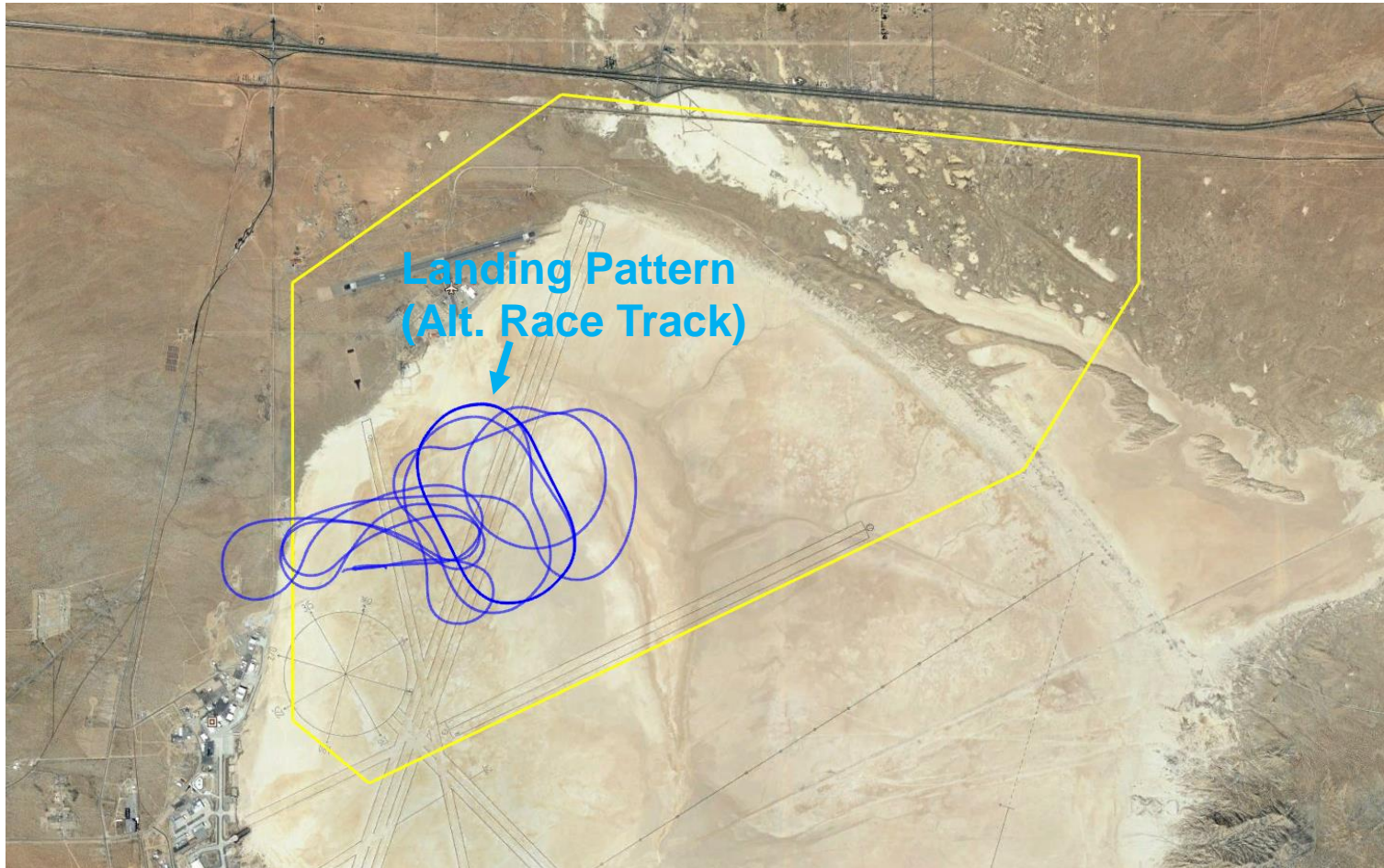
Duration: Approximately 29 minutes

Wing Tip Configuration: Rigged down, commanded to 0° for take off and landing, folded wing tips in 15° increments up to 45 ° down

Flight pattern: Landing pattern (Alternate smaller racetrack)



# Race track – Flight 1





# Flight 1 Details

- Pilot familiarization included manual take-off and flying figure 8s
- Once the pilot felt comfortable with the handling of PTERA, control of aircraft handed to the backup autopilot system, Piccolo
- Piccolo (lost comm back-up) Autopilot tested
  - Verified it tracks to the lost communication waypoint
  - Aircraft handling dynamics observed and no tuning required
  - Piccolo Autopilot performance excellent
- PTERA control is next handed to AREA-I's Autopilot
  - Vehicle handled exceptionally
  - Confirmed no tuning of gains required
  - Verified the AREA-I Autopilot is able to track the landing pattern
- Landing pattern (alternate smaller racetrack) is flown and winglets are incremented by 15 °down to 45°
  - Aircraft performed as expected with the wingtips deflected in the down position
  - No issues on the timing of the winglet motion – Observed 2 minutes for the heating cycle and 1 minute for the cooling cycle per 15 °increment

# Flight 2

Date: Friday December 15, 2017

Time: Approx. 12:49pm

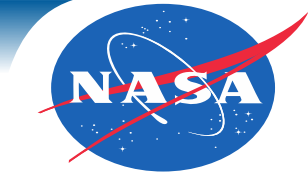
Purpose: Folded wingtips to  $-70^\circ$  to perform system ID maneuvers for 70kts & 90 kts

Duration: Approx. 37 mins

Configuration: Rigged down, commanded to  $0^\circ$  for take off and landing, folded wing tips to  $-70^\circ$  for maneuvers

Flight pattern: Main race track and smaller alternate race track

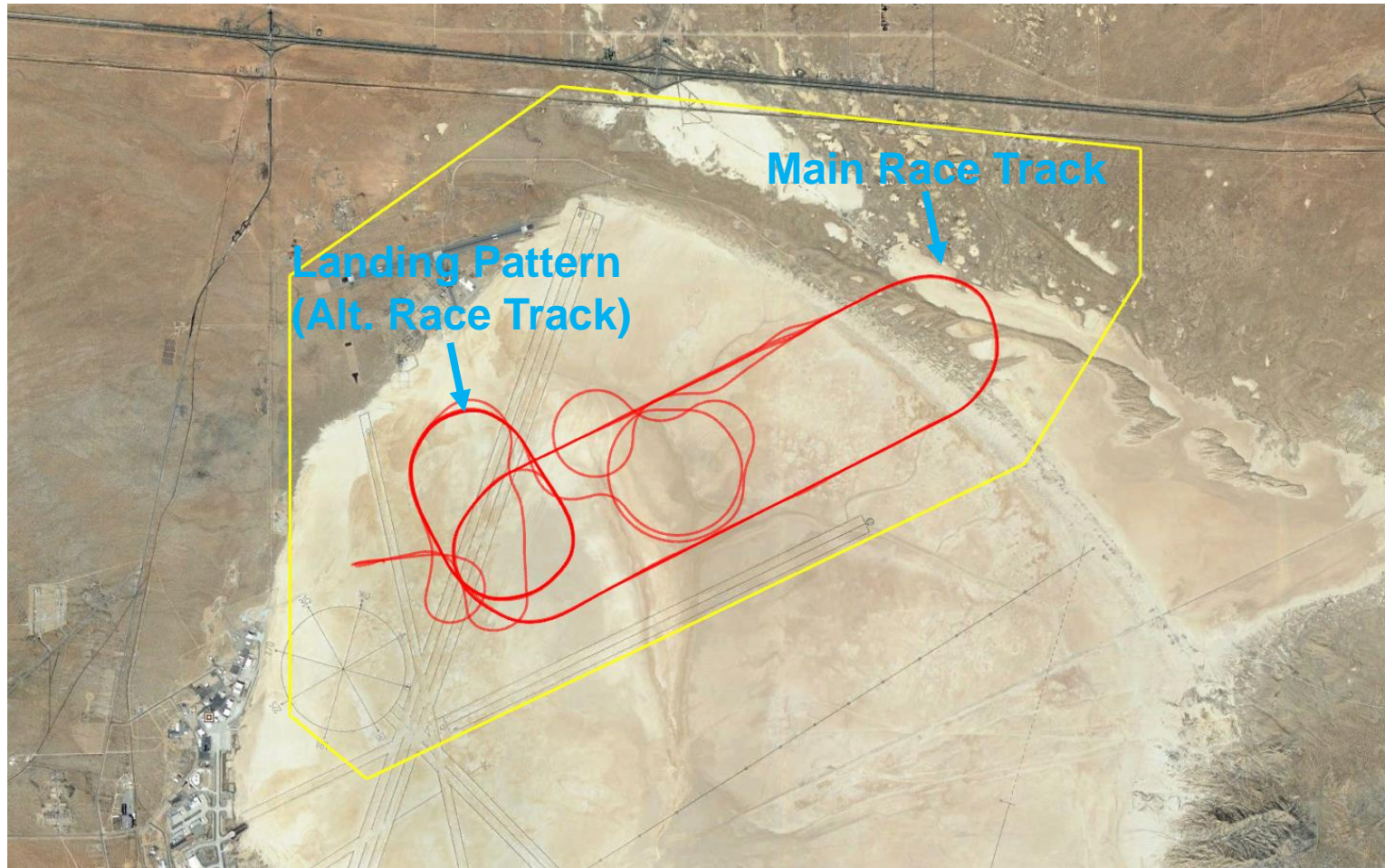


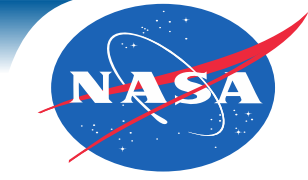


# PTERA Flight Test 2



# Flight 2 Path





# Flight 2 Details

- Immediately after take-off and on-condition altitude, AREA-I Autopilot was engaged
- Main racetrack flown
- SMAs were actuated to the  $-70^\circ$  position
- System ID maneuvers completed successfully for 70kts & 90kts
- Cooling of wingtips took longer than expected causing the landing to be completed with wingtips deflected down to  $-30^\circ$  for the right and  $-20^\circ$  for the left
- Aircraft again performed nominally and landed safely without issue
- $45^\circ$  bank maneuver had negligible response

# Third Flight

Date: Friday December 15, 2017

Time: Approx. 3:40pm

Purpose: Folded wingtips to 70° to perform system ID maneuvers at 80kts

Duration: Approx. 33.5 mins

Configuration: Rigged up, commanded to 0° for take off and landing, folded wing tips up to 70° for maneuvers

Flight pattern: Main race track

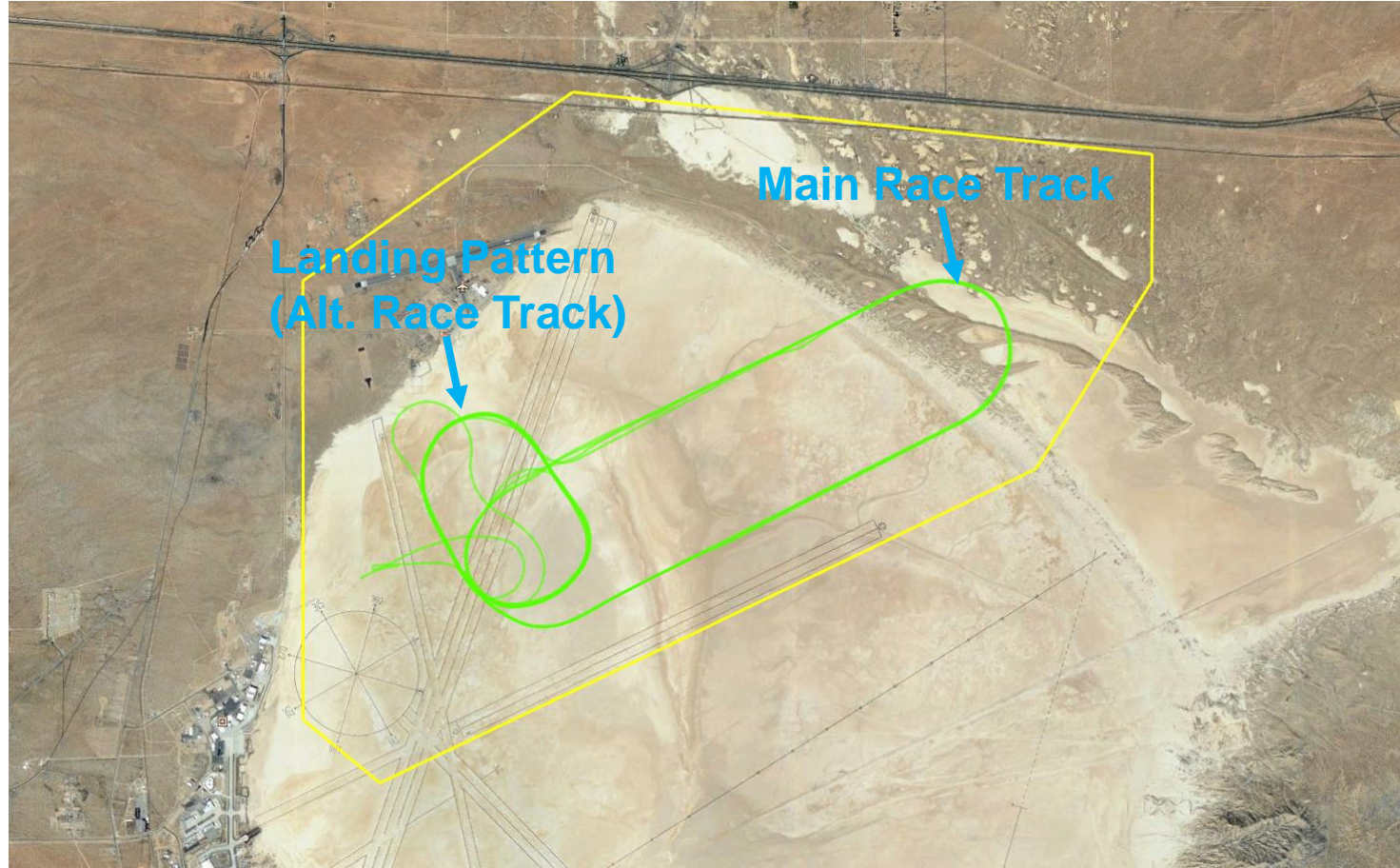


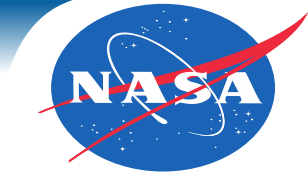


# PTERA Flight Test 3



# Flight 3 Path





# Flight 3 Details

- SMA reconfigured for folding wings up
- Immediately after take-off and on-condition altitude, AREA-I onboard controller was engaged
- Full racetrack flown
- SMAs were actuated to the +70° position
- System ID maneuvers completed successfully at 80 kts
- Aircraft landed safely without issue

# Results

- Successfully flew three flights
  - Articulated full  $70^\circ$  to  $-70^\circ$  range
- Full mission success
  - Performed maneuvers at deflected wing tip positions
  - Aircraft performed nominally
- Flight validated simulation
  - Next step development of CLAWS
  - Able to virtually eliminate rudder



## Yawing Moment due to Sideslip

