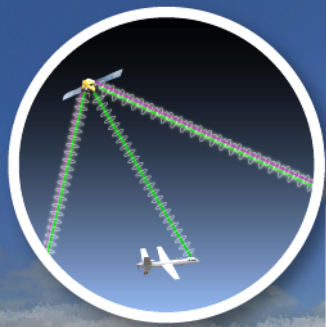
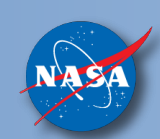


# Modeling and Simulation Plans in Support of Low Cost, Size, Weight, and Power Surveillance Systems for Detecting and Tracking Non-Cooperative Aircraft.

Gilbert Wu  
Confesor Santiago

SC-228 Modeling and Simulation Meeting





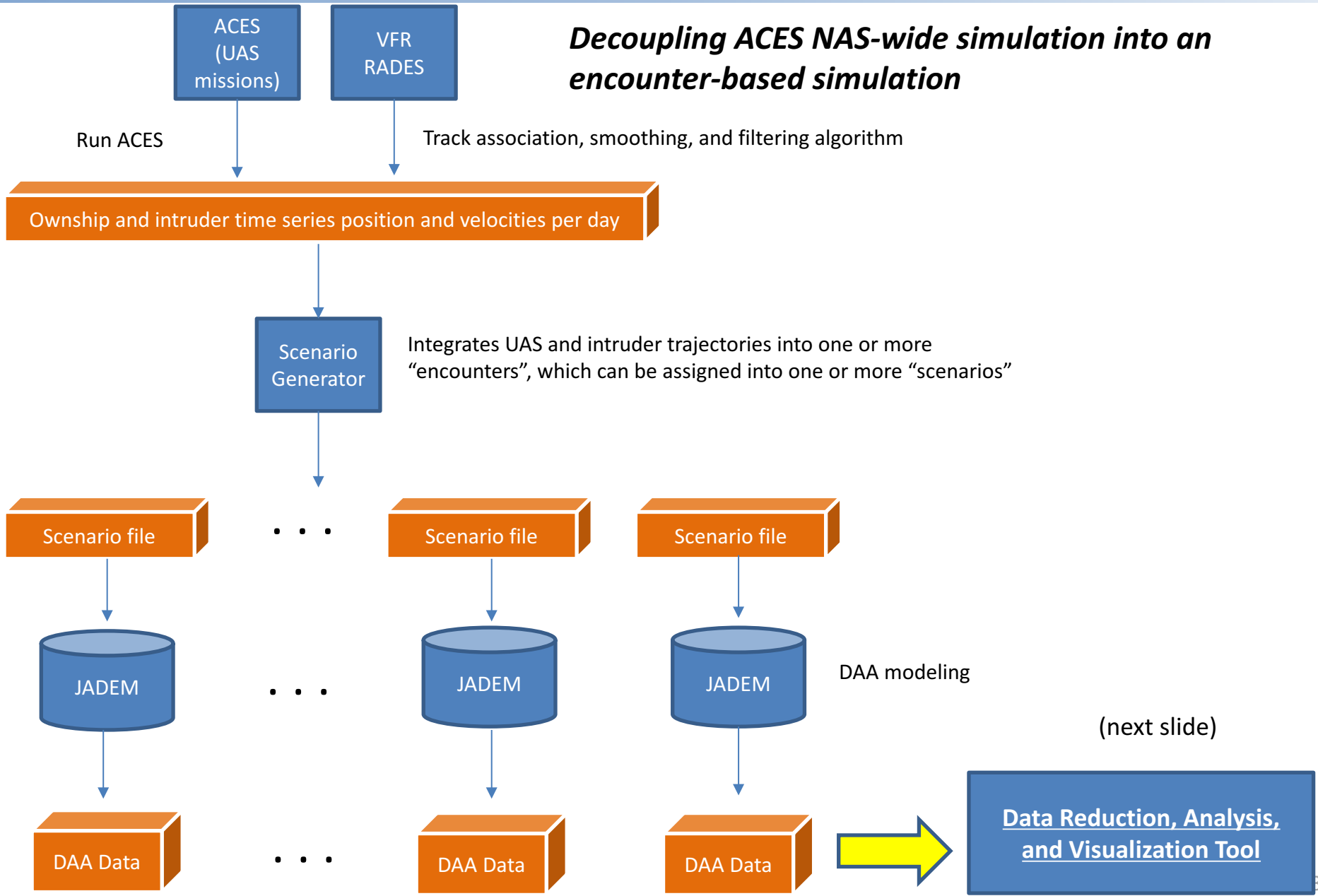
# Outline

- Simulation platform for end-to-end verification and validation system
  - Simulation improvements to support Phase 2 MOPS development
  - Java Architecture for DAA Extensibility and Modeling (JADEM) and Detect and Avoid Alerting Logic for Unmanned Systems (DAIDALUS) integration
  - Sensor and Pilot Models
- Planned Modeling and Simulation Work
  - Mainly supports MOPS for low cost, size, weight, and power surveillance (C-SWaP) to detect and track non-cooperative aircraft
  - Expected results
- Flight Test 5 &6



# Transformed Fast-Time Simulation Architecture

*Decoupling ACES NAS-wide simulation into an encounter-based simulation*

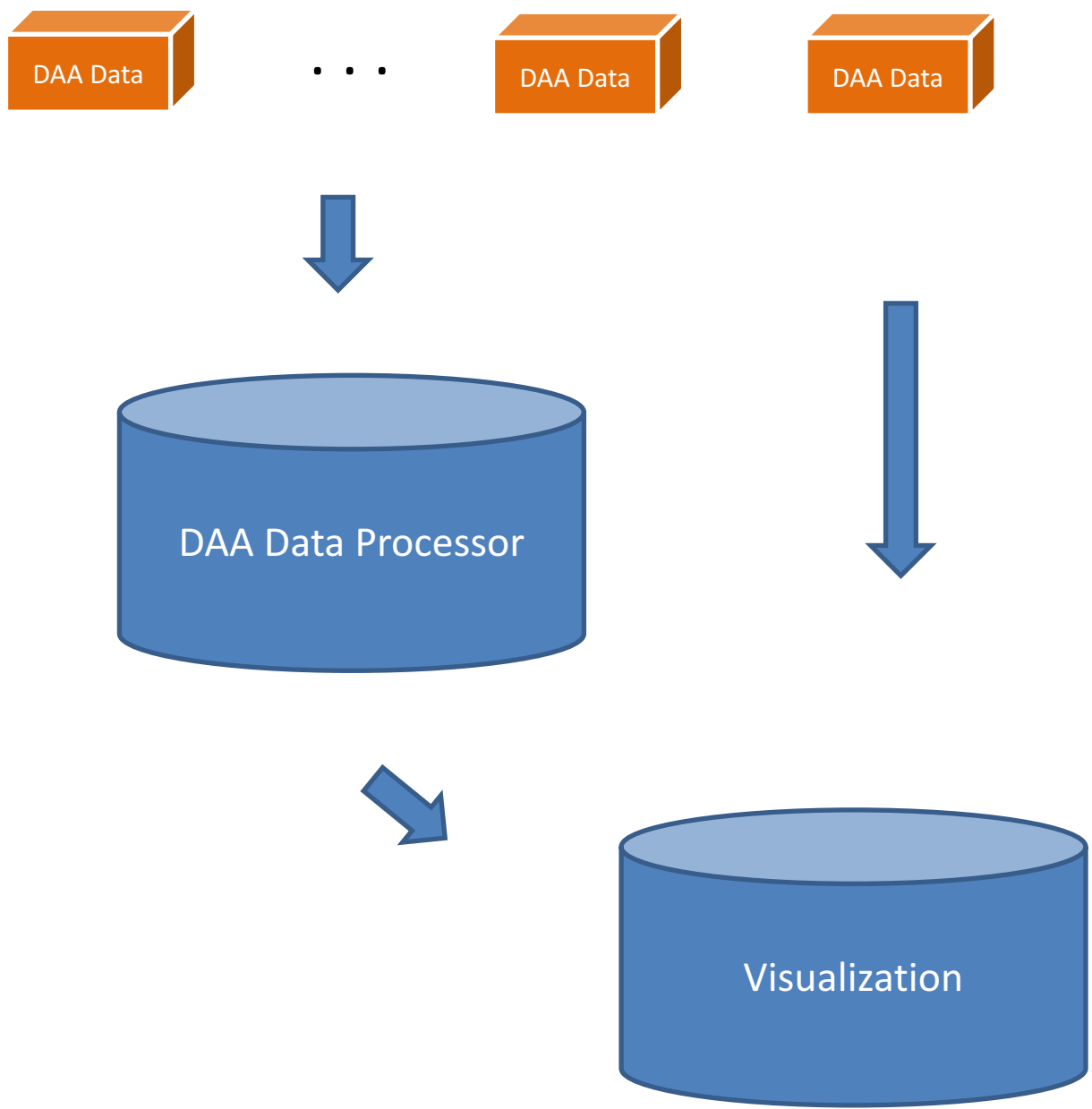


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Data Reduction, Analysis, and Visualization Tool



# Transformed Fast-Time Simulation Architecture (cont.)





# Event Hierarchy

NAS-wide

Scenarios

Encounters

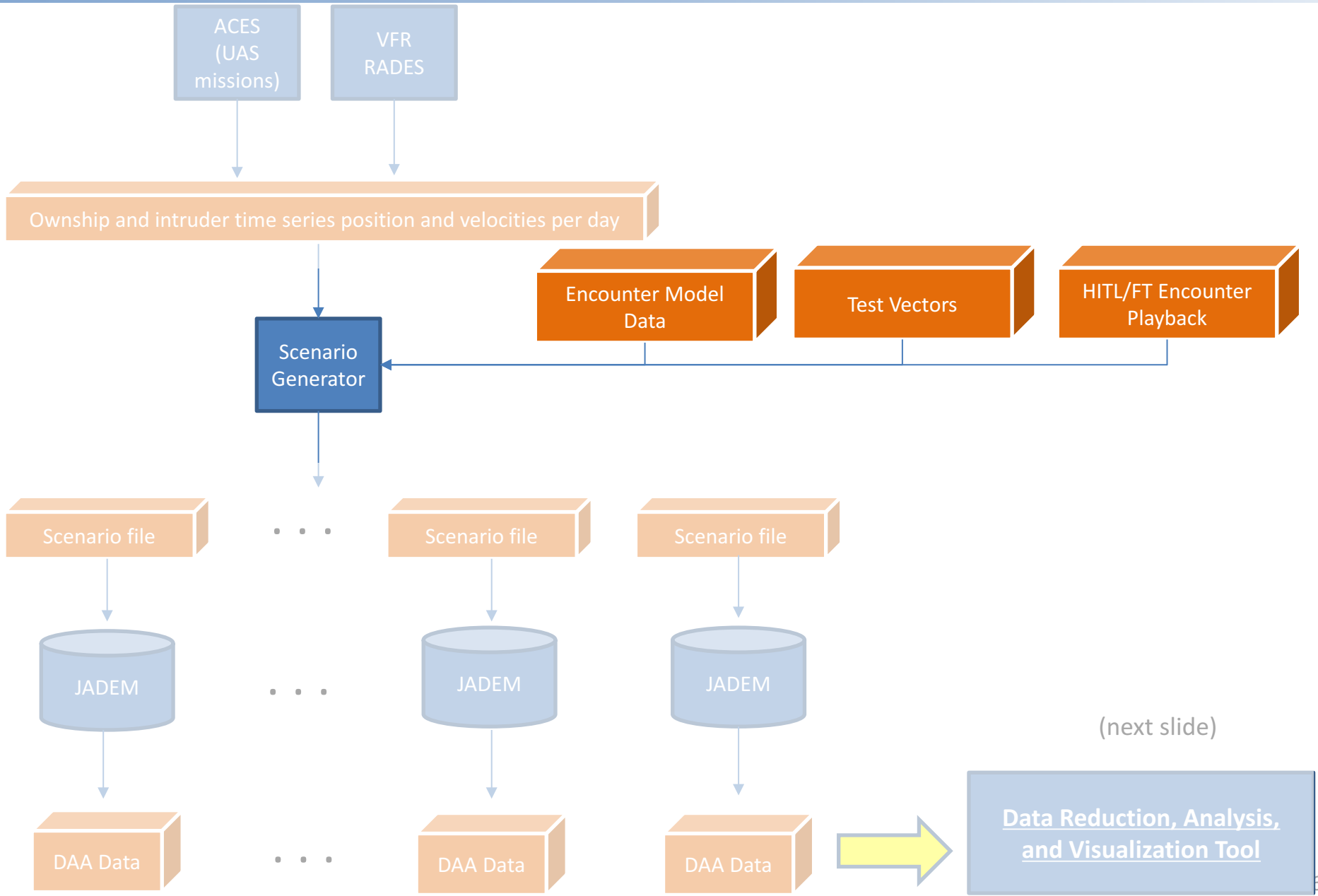
DAA Alerts

LoWCs

NMACs



# Integration with Other Datasets

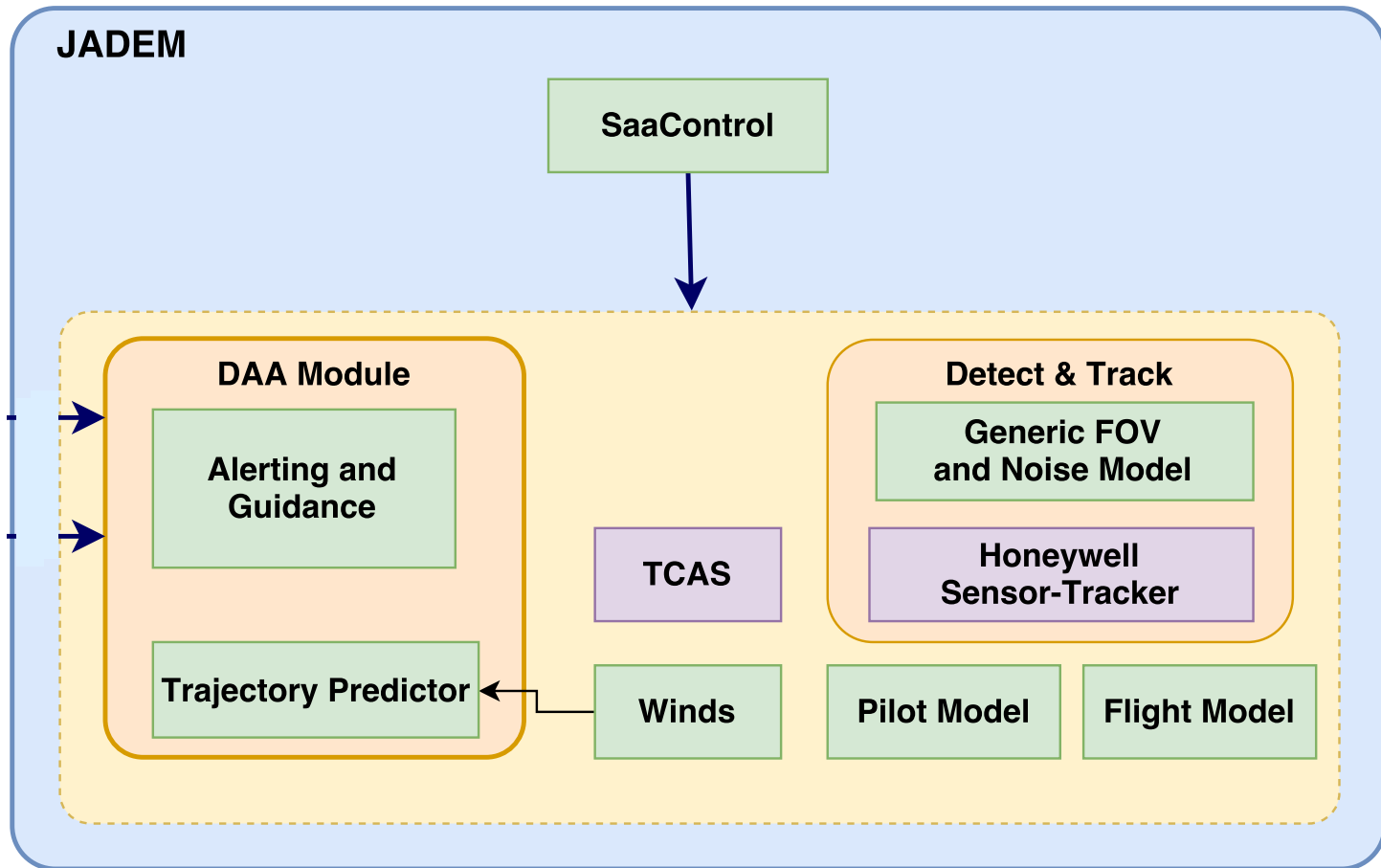


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Data Reduction, Analysis, and Visualization Tool

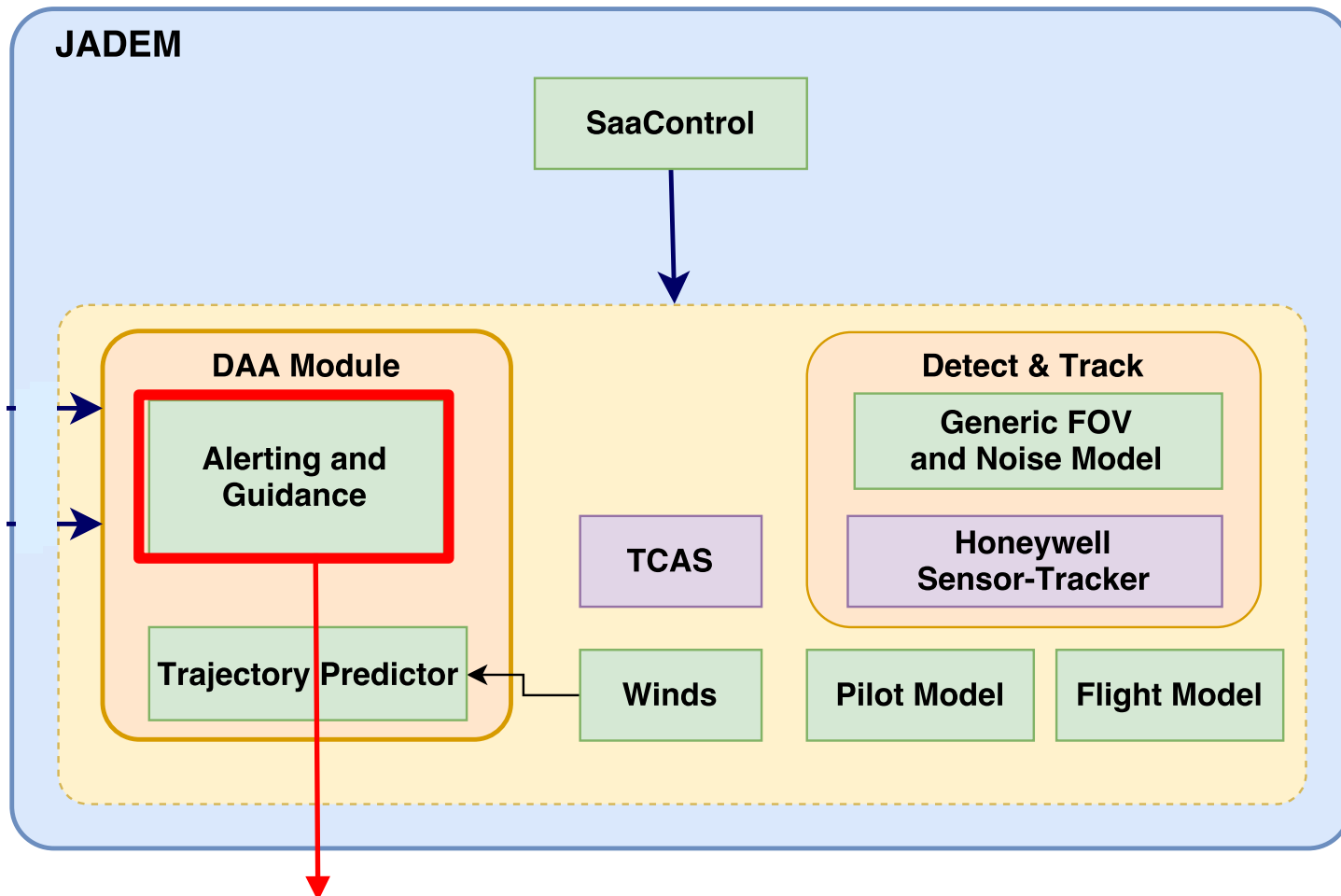


# JADEM Architecture





# JADEM Architecture



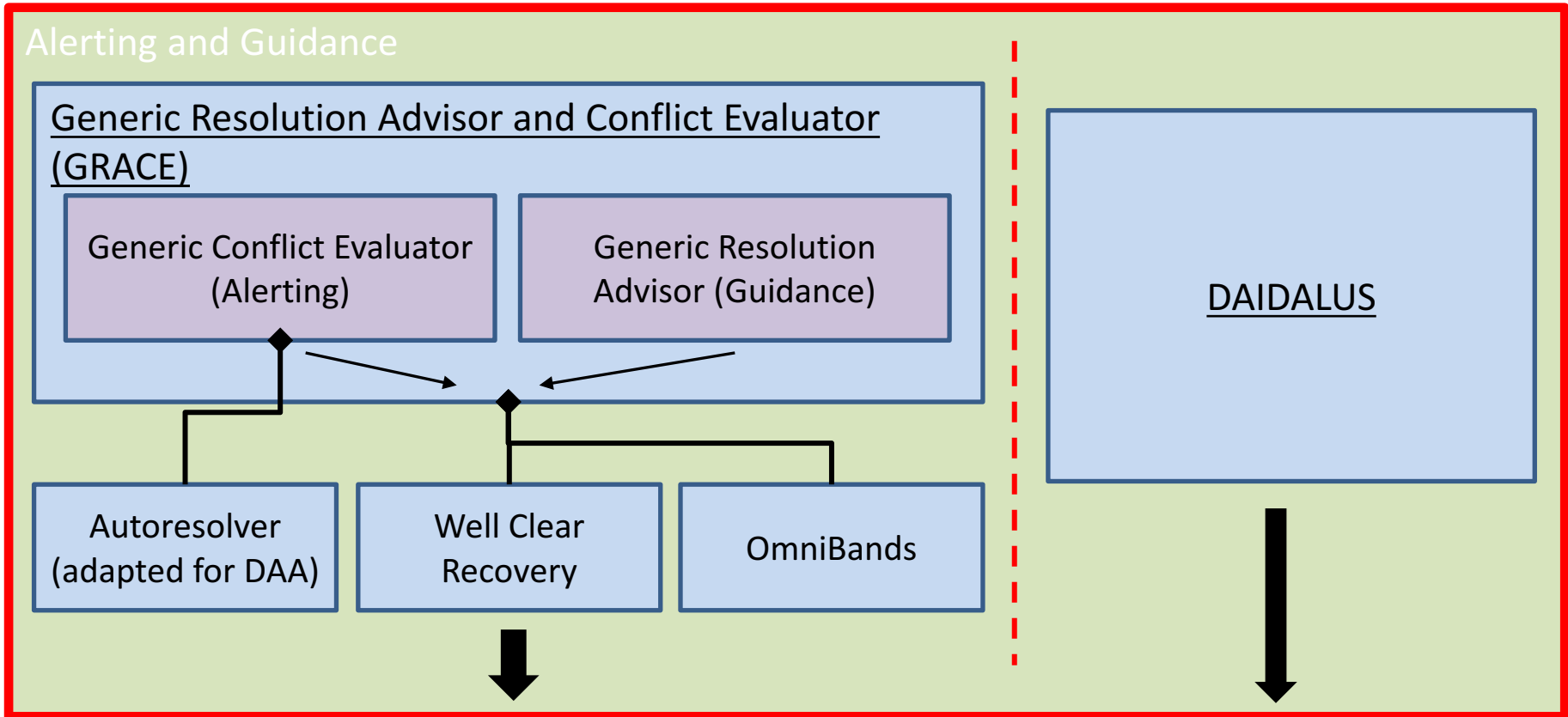
**Where NASA has integrated various DAA algorithms...**





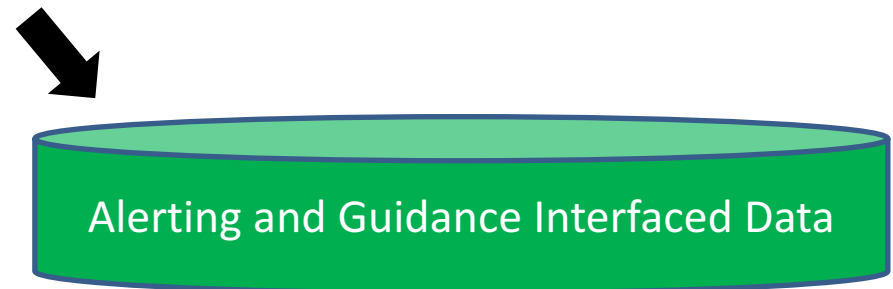
# JADEM/DAIDALUS Integration

## JADEM -



### Not shown:

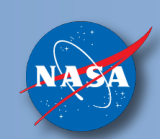
- MOPS-compliant alerting comes from "Generic Conflict Evaluator"
- Trial Planner is another guidance configuration (from IHITL/PT5 days)





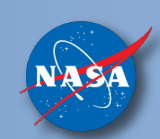
# Models

- Sensor models
  - Leveraging existing sensor models developed by Honeywell
    - Air-to-air radar (Phase 1)
    - ADS-B
    - Mode C/S
    - Honeywell Fusion Tracker
  - Low SWaP radar model to be developed under new cooperative agreement with partner (selection made, still under negotiation)
  - Reference track processing algorithm for low SWaP radar MOPS (to be developed under cooperative agreement)
- Pilot Model - Continue development of pilot model NASA used in Phase 1 ACES simulations
  - Key features:
    - Alert generation
    - Alert evaluation time delay
    - Maneuver determination
    - Maneuver execution time delay
  - Challenges
    - Surveillance uncertainty
    - Intruder accelerations
    - Maneuver reversals



## **Planned Fast-Time Simulation Activities:**

Supporting Low Cost, Size, Weight, and Power  
Surveillance for Detecting and Tracking Non-  
Cooperative Aircraft



# Planned Fast-Time Simulation Activities

- Low C-SWaP Fast-Time Simulation 1 (FY17/18)
  - A.k.a. – Low C-SWaP DAA Well Clear Trade Study
- Low C-SWaP Fast-Time Simulation 2 (FY18)
- Low C-SWaP Fast-Time Simulation 3 (FY19)



# DWC Trade Study for Non-Cooperative (Sim 1)

- Develop an alternative DAA Well Clear (DWC)
  - Low C-SWaP UAS
  - Phase 1 UAS
- Low C-SWaP UAS
  - Phase 1 sensor for non-cooperative aircraft (radar) consumes too much power and is too heavy for many UAS
  - Low C-SWaP sensors (range < 3 nmi for example) leaves little time to detect and remain DWC
  - Example: head-on encounter
    - ownship 100 kts, intruder 170 kts
    - At ~3.4 nmi, ownship cannot maintain well clear (bands saturated)
- Phase 1 UAS
  - Phase I DWC largely driven by TCAS II interoperability consideration
    - Definition type, h, HMD, and modTau
    - Thresholds of variables
  - Better consistency between Phases 1 and 2

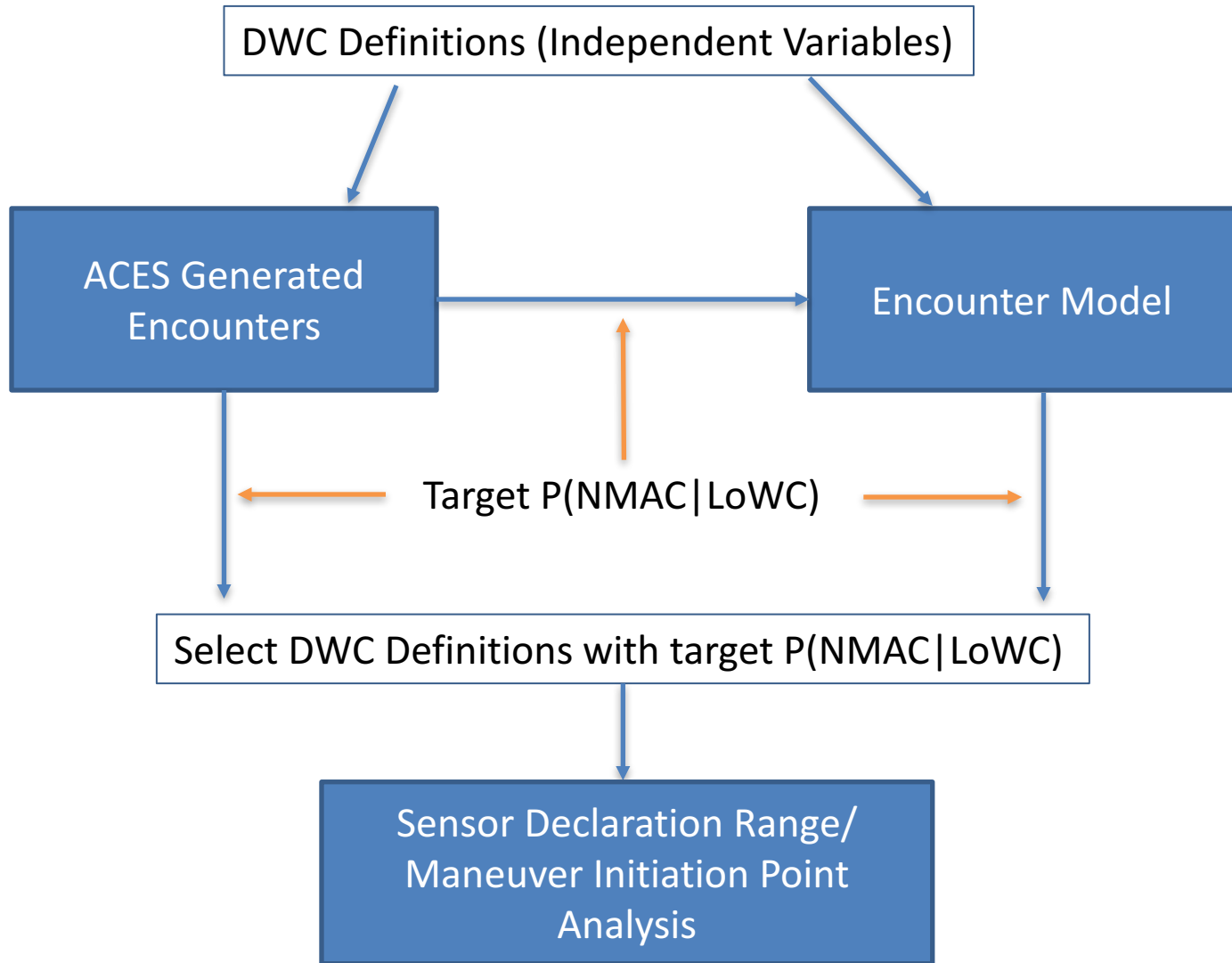


# Objectives

- Investigate trade space for DWC definition(s) for non-cooperative aircraft
- Collect data to inform sensor declaration range/maneuver initiation point analysis (AAG)
- **Recommend alternative DWC definition(s) for the SC-228 to consider for non-cooperative aircraft**



# Workflow Diagram





# Independent variables

- DWC types and threshold values (\* for threshold)
  - DWC1:  $h^*$ ,  $HMD^*$ ,  $modTau^*$
  - DWC2:  $h^*$ ,  $HMD^*$ ,  $t_{pz}^*$
  - DWC3: Static hockey puck:  $h^*$ ,  $R^*$
  - DWC4: Dynamic hockey puck:  $h^*$ ,  $R^*(rdot) = a^* + rdot \times b^*$

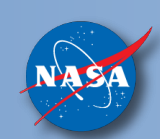
Type	$h^*$ (ft)	$HMD^*$ (ft)	$modTau^*$ (sec)
DWC1	450	[2000, 9000]	[15, 35]

Type	$H^*$ (ft)	$HMD^*$ (ft)	$T_{pz}^*$ (sec)
DWC2	450	[2000, 9000]	[15, 35]

Type	$H^*$ (ft)	$R^*$ (ft)	
DWC3	450	[2000, 15000]	

Type	$H^*$ (ft)	$a^*$ (ft)	$b^*$ (sec)
DWC4	450	TBD	TBD





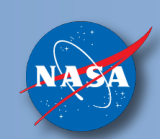
# Schedule

Milestone	Date
ACES Encounter data generation	8/14/17
Software tool feature complete	9/12/17
Data analysis complete	10/3/17
Preliminary results brief	10/10/17
Feedback, adjustment, and aligning with Lincoln Lab analysis	11/30/17
Final briefing	12/4/17



# Low C-SWaP Fast-Time Simulation 2

- **Objective:** Unmitigated fast-time simulation with (and without) surveillance uncertainty to explore alerting performance requirements for low C-SWaP surveillance
- **Scenarios**
  - Encounters from NAS-wide simulations (UAS missions vs. VFR RADES)
  - New MIT-LL low C-SWaP encounter model
- **Models**
  - Low C-SWaP UAS aircraft performance
  - Low C-SWaP radar sensor uncertainty
  - Tracking processing
  - JADEM with DAIDALUS updated for low C-SWaP DWC definition
- **Result**
  - Results to inform new alerting and guidance requirements for low C-SWaP surveillance, i.e., non-hazard zone, alerting/guidance special cases, late alert threshold, early alert threshold, etc.
  - First version of low C-SWaP radar test vectors and alerting performance
- **Schedule**
  - Start FY18
  - To be completed 9/30/18



# Low C-SWaP Fast-Time Simulation 3

- **Objective:** Unmitigated and mitigated fast-time simulation with (and without) surveillance uncertainty to verify and validate alerting and guidance requirements
- **Scenarios**
  - Encounters from NAS-wide simulations (UAS missions vs. VFR RADES)
  - New MIT-LL low C-SWaP encounter model
  - Selected encounters from Flight Test 5
  - Selected encounters from Low C-SWaP HITL
- **Models**
  - Low C-SWaP UAS aircraft performance
  - Low C-SWaP radar sensor uncertainty (updated from Flight Test 5 results)
  - Tracking processing (updated from Flight Test 5 results)
  - JADEM with DAIDALUS updated for low C-SWaP DWC definition
  - Pilot model
- **Result**
  - Results to finalize take-away's from Sim 2, LoWC/NAMC risk ratios, and other open- and closed-loop performance metrics from MOPS
  - Final version of low C-SWaP radar test vectors and alerting performance
- **Schedule**
  - Start FY19
  - To be completed 9/30/19



- Just completed selection of partner (and non-selections)
  - Cooperative agreement = cost-sharing
- Honeywell was selected
- Low C-SWaP radar - basis for our flight test supporting development of low C-SWaP radar performance standards
- Also supports modeling and simulation of low C-SWaP radar
  - Sensor modeling and track processing
- Still in negotiation, cooperative agreement not awarded yet



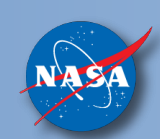
# Flight Test 5

- UAS: SIERRA-B (similar to Shadow UAS)
- Edwards AFB airspace
- Equipped with partner (Honeywell) low C-SWaP surveillance system for detecting and tracking non-cooperative aircraft
- Existing aircraft GCS and legacy C2 systems
- Scripted air-to-air encounters against single and multiple manned intruders
- Objectives:
  - Development of sensor performance requirements
  - Verify/validate models and simulation results
  - Verify interoperability of low C-SWaP sensor requirements with existing DAA alerting and guidance requirements
- Data collection: September-November 2018



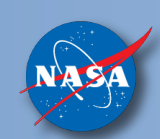
# SIERRA-B





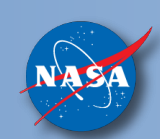
# Flight Test 6

- Similar to FT5, but with matured and enhanced systems
- Vigilant Spirit Control Station instead of SIERRA-B's legacy GCS
- Baselined for taking place at Edwards AFB, but could take place at another mutually-agreed-upon test site
- Could also include cooperative surveillance systems such as "lesser SWAP" ADS-B and Active Surveillance (option we are considering)
- More to be defined as we work through simulations and SC-228 Phase 2 MOPS needs
- Data collection summer of 2019



Questions?





BACKUP



# Planned Fast-Time Simulation Activities

**Objective:** Trade-study to analyze alternative DWC definitions for non-cooperative aircraft (Phase 1 UAS performances and new, relatively lower UAS performances in Phase 2)

**Result:** Candidate DWC definitions for SC-228 to consider for Phase 2 MOPS

**Schedule:** To be completed by 12/10/17

## Low C-SWaP Fast-Time Sim 1

**Objective:** Unmitigated fast-time simulation with (and without) surveillance uncertainty to explore alerting performance requirements for low C-SWaP surveillance

**Result:** Results to informed new alerting and guidance requirements for low C-SWaP surveillance , i.e., non-hazard zone, alerting/guidance special cases, late alert threshold, early alert threshold, etc.

**Schedule:** To be completed by 9/30/18

## Low C-SWaP Fast-Time Sim 2

**Objective:** Unmitigated and mitigated fast-time simulation with (and without) surveillance uncertainty to V&V alerting and guidance requirement

**Result:** Results to finalize take-away's from Sim 2, LoWC/NAMC risk ratios, and other open- and closed-loop performance metrics from MOPS

**Schedule:** To be completed by 9/30/19

## Low C-SWaP Fast-Time Sim 3