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GOVERNMENT INITIATIVES (AGI)

Simulation Based Digital Acquisitions

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Thursday Oct 31st || NDIA Systems and Missions Engineering Conference

Agenda

- Introduction
- Digital Acquisition Perspective
  - Problem Statement
  - Dataflow in Digital Acquisition
- Methods for Delivering Simulation
  - Why use each method?
  - Making decisions from executable simulation artifacts
- Conclusions

What we do: Simulation Solutions from Mission to Microchip

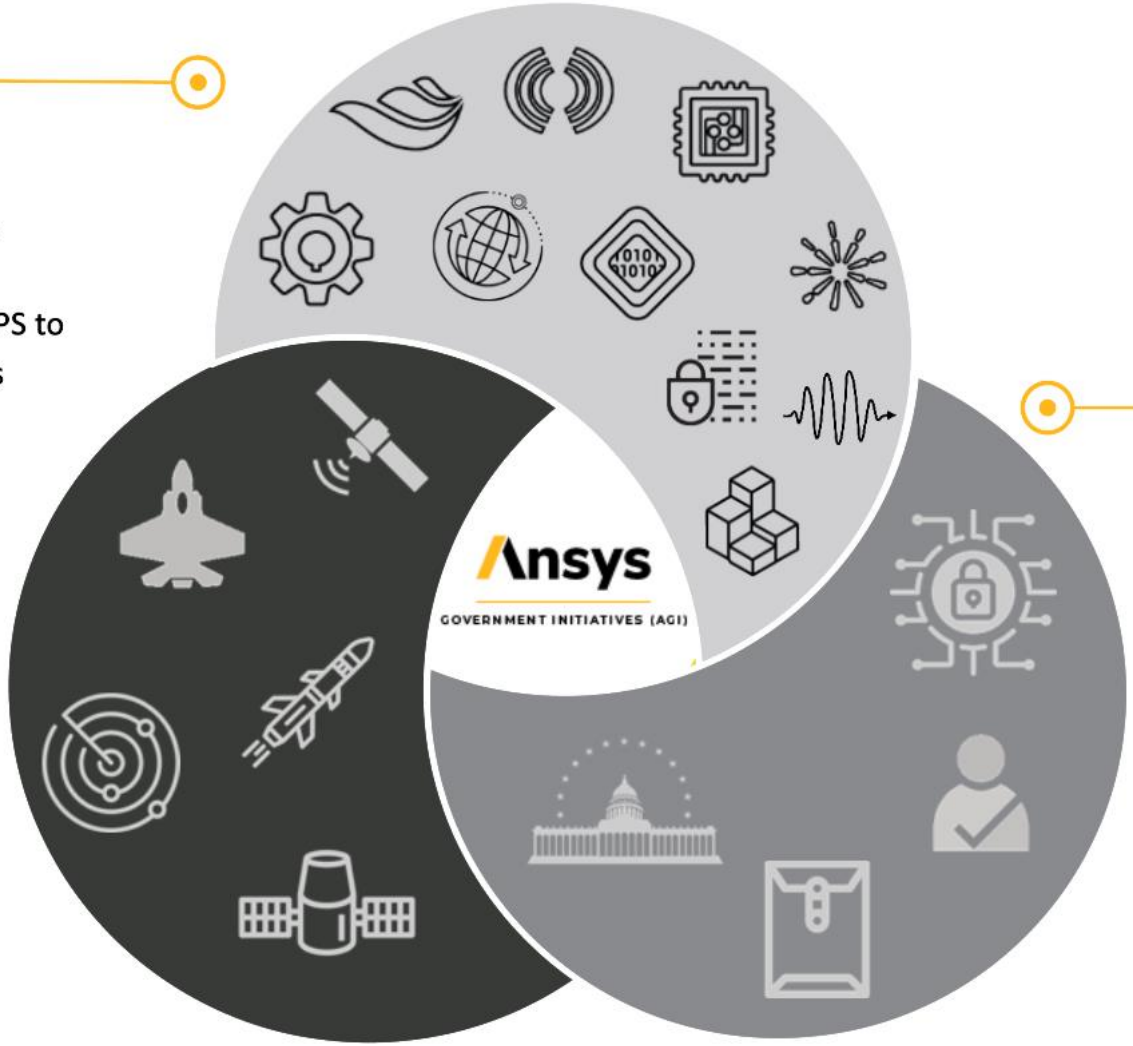
50+ Years of Innovation

Industry leading solutions across physics, systems, safety, materials, and missions

- Intelligent, open, and agile platform to evaluate overall system performance
- Only company that can support CONOPS to detailed engineering for RFP responses
- 375+ technology partners

Domain and Mission Expertise

- Space systems
- Aircraft and UAV systems
- Communications and radar analysis
- Missile defense
- Intelligence, surveillance, and reconnaissance



From the crucial role of *open environments* to the essential principles of *implementation,* Ansys invites you to explore how organizations can unlock the transformative potential of *digital engineering*.

30+ Years of National Security Expertise

- Deploying modeling and simulation in the national security environment
- Classified business and technical support
- Program capture and program execution
- Able to support you within your environments
- FEDRamped

But how can this simulation fit into a deliverable architecture?

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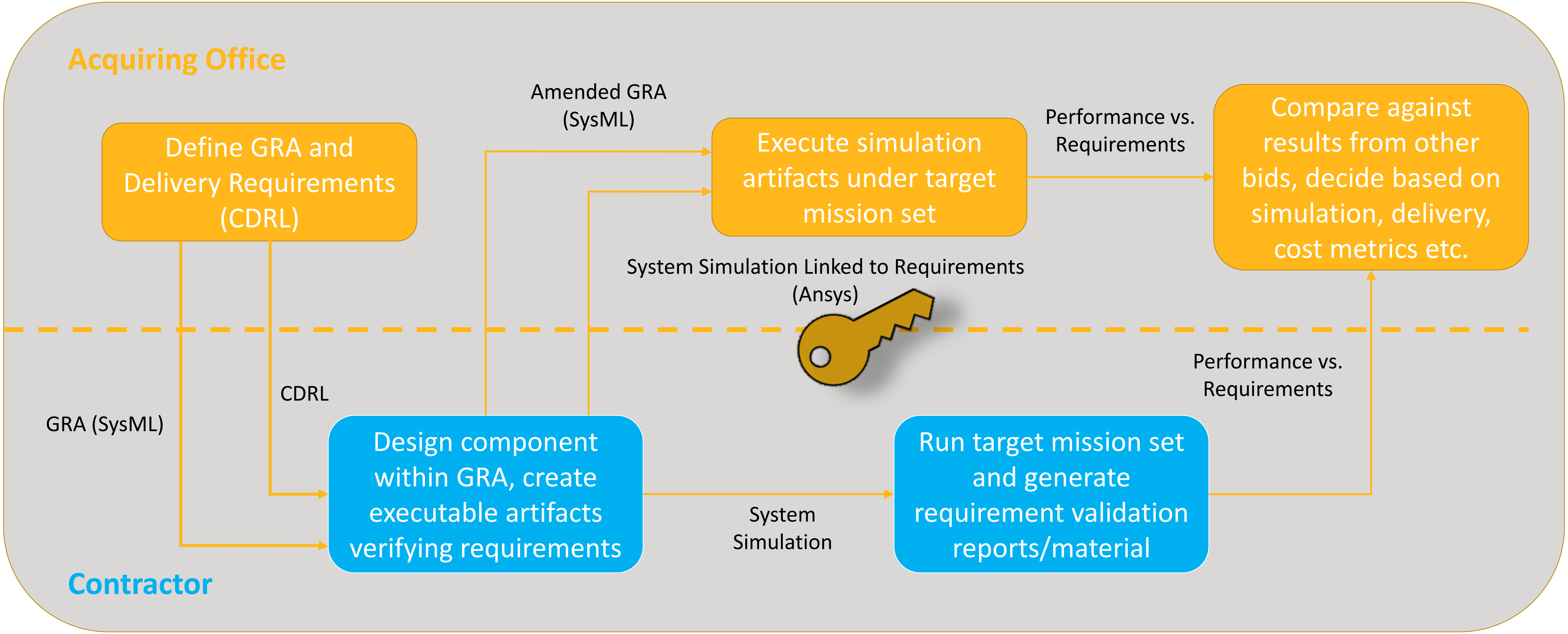
Digital Acquisition Perspective

Problem Statement

For a digital acquisition process to provide ***utility greater than the adoption cost*** it is not enough to deliver/receive “flat” artifacts like SysML diagrams. The deliverables ***must be executable*** within a framework that simulates, to the highest fidelity available, the ***intended mission***. In addition, those simulations must be executable ***by the acquiring office and the contractor alike***.

- Key tenants:
  - Executable models are key to realizing the benefit of digital engineering
  - Simulation artifacts must be accessible/executable by both sides
  - The format of simulation delivery can vary and should be specific to the acquisition

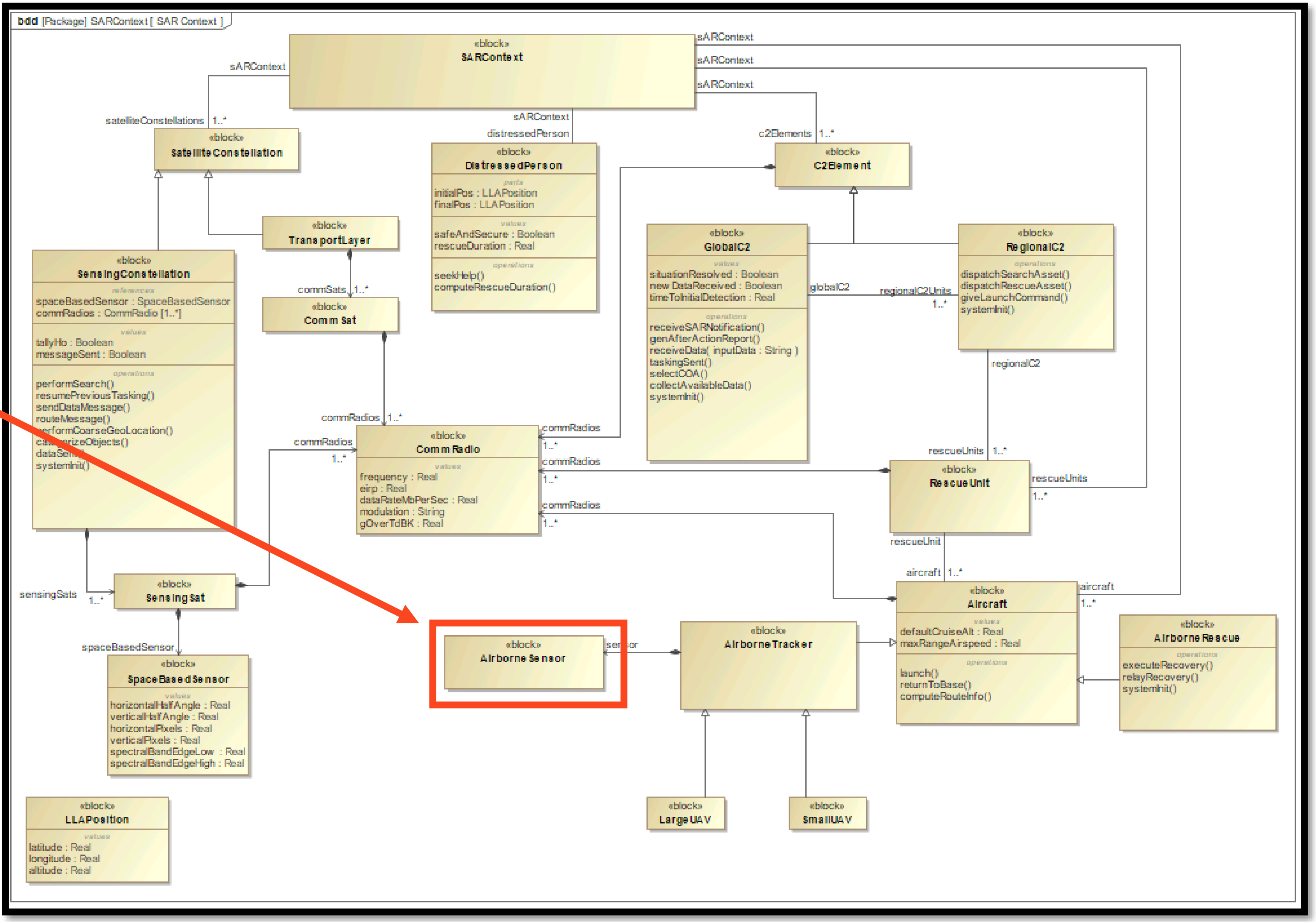
Dataflow for Simulation-Based Acquisition



Government Reference Architecture (GRA)

- Intended mission is baked into the elements provided
- Room for contractor adding components that they intend to deliver
- Performance requirements specified within model

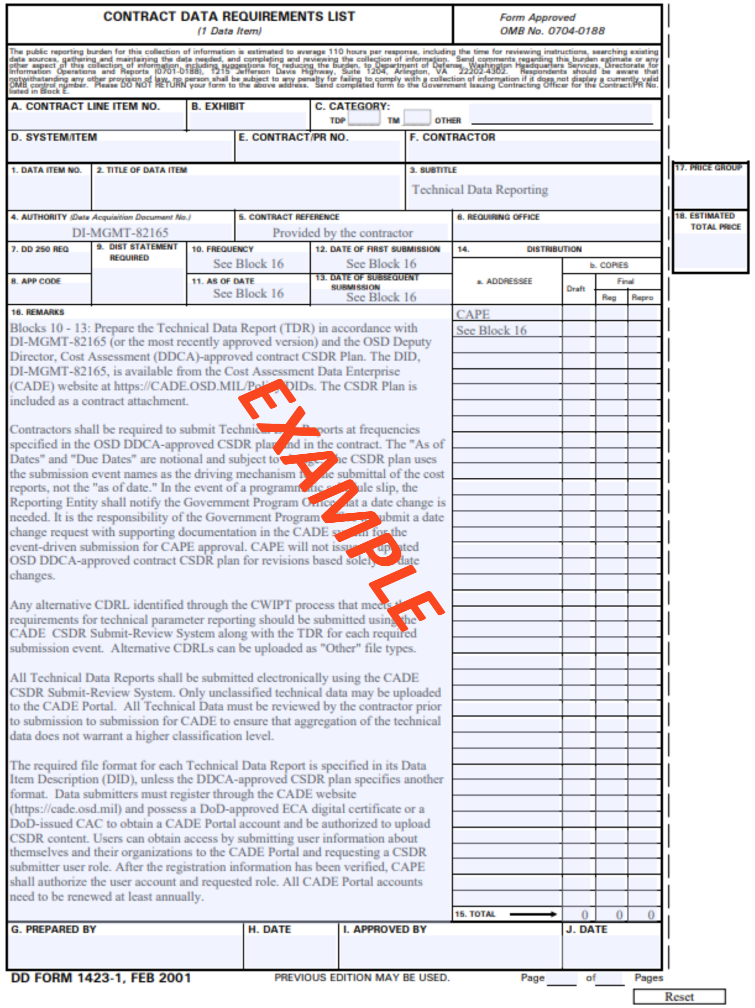
#	Name	Text
1	AirborneTracker	
2	AT-1 Unmanned	The airborne tracker shall be unmanned.
3	AT-2 Control Range	Must be controllable from a range of up to 50 nm
4	AT-3 Imaging	UAV must carry imaging equipment that allows for the detection of a human on land or at sea, during day or night, in all weathe
5	AT-4 Data Stream	UAV must be able to transmit a scene image to appropriate recipients
6	AT-4.1 Terrestrial Link SNR	Must support links with an SNR of at least 10dB across a distance of at least 100nm
7	AT-4.2 SatComm Link SNR	Support link with an SNR of at least 30dB to the transport layer at all times.
8	GlobalC2	
9	C2-1 Receive Distress Alert	GlobalC2 must be capable of receiving distress alerts 24 hours per day, every day of the year.
10	C2-2 Persistent Communications	GlobalC2 must be capable of 2-way communications with any and all regional C2 agencies during all active SAR operations.
11	Mission	
12	M-1 Initial Detection	Distressed persons shall be located by satellite assets in less than 180 minutes
13	M-2 Recovery	Total time until recovery shall be less than 8 hours
14	TransportLayer	
15	TL-1 Assured Connectivity	The satellite transport layer shall provide assured data and connectivity service worldwide to a full range of platforms.
16	TL-2 Resilient Connectivity	The satellite transport layer shall provide resilient data and connectivity service worldwide to a full range of platforms.
17	TL-3 Low-latency Connectivity	The satellite transport layer shall provide low-latency data and connectivity service worldwide to a full range of platforms.
18	TL-4 LEO Constellation	The constellation will consist of at least 300 and no more than 500 Low Earth Orbit (LEO) satellites
19	TL-4.1 Satellite Altitude	Satellite altitude must be at least 750 km and must be less than 1200 km.
20	TL-1.2 Single Satellite View Coverage	With a full constellation, 99% of the Earth's surface will have at least 1 satellites in view at all times.
21	TL-1.1 Two Satellite View Coverage	With a full constellation, 95% of the Earth's surface will have at least 2 satellites in view at all times.
22	TL-3.1 Satellite Cross Links	The constellation shall be interconnected with Optical Inter-Satellite Links (OISLs)
23	TL-2.1 Reconfigure	With 1 failed satellite, the constellation must be capable of reconfiguring to provide baseline coverage in less than 12 hours.
24	TL-2.2 Degraded Coverage	With 90% of a full constellation, 80% of the Earth's surface will have at least 1 satellite in view at all times.
25	TL-5 RF Bands	The constellation shall support RF communications over multiple bands
26	TL-5.2 Link-16	Constellation will support Link-16 communications.
27	TL-5.1 Ka Band	Constellation will support Ka band communications.



GRA built to integrate with simulation formats the CDRL written accordingly…

Contract Data Requirements List (CDRL)

- Data delivery requirements can be written to take advantage of simulation-based digital acquisition
  - Requesting delivery of structures in SysML
  - Requesting format of simulation artifacts
- Requesting data in open formats enables tool decisions (no vendor lock)
- Simulation artifacts should be required to deliver with walkthrough and execution information
- Simulation results documented such that they can be reproduced on either side



CONTRACT DATA REQUIREMENTS LIST
(1 Data Item)

Form Approved
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The public reporting burden for this collection of information is estimated to average 110 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0701-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. Please DO NOT RETURN your form to the above address. Send completed form to the Government Issuing Contracting Officer for the Contract/PR No. listed in Block E.

A. CONTRACT LINE ITEM NO. | B. EXHIBIT | C. CATEGORY: TDP TM OTHER

D. SYSTEM/ITEM | E. CONTRACT/PR NO. | F. CONTRACTOR

1. DATA ITEM NO. | 2. TITLE OF DATA ITEM | 3. SUBTITLE: Technical Data Reporting | 17. PRICE GROUP

4. AUTHORITY (Data Acquisition Document No.): DI-MGMT-82165 | 5. CONTRACT REFERENCE: Provided by the contractor | 6. REQUIRING OFFICE | 18. ESTIMATED TOTAL PRICE

7. DD 250 REQ | 9. DIST STATEMENT REQUIRED | 10. FREQUENCY: See Block 16 | 12. DATE OF FIRST SUBMISSION: See Block 16

8. APP CODE | 11. AS OF DATE: See Block 16 | 13. DATE OF SUBSEQUENT SUBMISSION: See Block 16

14. DISTRIBUTION: a. ADDRESSEE	b. COPIES: Draft	Final: Reg	Final: Repro
CAPE			
See Block 16			
15. TOTAL →	0	0	0

16. REMARKS

Blocks 10 - 13: Prepare the Technical Data Report (TDR) in accordance with DI-MGMT-82165 (or the most recently approved version) and the OSD Deputy Director, Cost Assessment (DDCA)-approved contract CSDR Plan. The DID, DI-MGMT-82165, is available from the Cost Assessment Data Enterprise (CADE) website at https://CADE.OSD.MIL/Pol[illegible]DIDs. The CSDR Plan is included as a contract attachment.

Contractors shall be required to submit Technic[illegible]ports at frequencies specified in the OSD DDCA-approved CSDR pla[illegible]nd in the contract. The "As of Dates" and "Due Dates" are notional and subject to [illegible]he CSDR plan uses the submission event names as the driving mechanism [illegible]e submittal of the cost reports, not the "as of date." In the event of a programm[illegible]ule slip, the Reporting Entity shall notify the Government Program O[illegible]at a date change is needed. It is the responsibility of the Government Program [illegible]ubmit a date change request with supporting documentation in the CADE s[illegible] for the event-driven submission for CAPE approval. CAPE will not issu[illegible]ted OSD DDCA-approved contract CSDR plan for revisions based solel[illegible]date changes.

Any alternative CDRL identified through the CWIPT process that meets [illegible] requirements for technical parameter reporting should be submitted using the CADE CSDR Submit-Review System along with the TDR for each required submission event. Alternative CDRLs can be uploaded as "Other" file types.

All Technical Data Reports shall be submitted electronically using the CADE CSDR Submit-Review System. Only unclassified technical data may be uploaded to the CADE Portal. All Technical Data must be reviewed by the contractor prior to submission to submission for CADE to ensure that aggregation of the technical data does not warrant a higher classification level.

The required file format for each Technical Data Report is specified in its Data Item Description (DID), unless the DDCA-approved CSDR plan specifies another format. Data submitters must register through the CADE website (https://cade.osd.mil) and possess a DoD-approved ECA digital certificate or a DoD-issued CAC to obtain a CADE Portal account and be authorized to upload CSDR content. Users can obtain access by submitting user information about themselves and their organizations to the CADE Portal and requesting a CSDR submitter user role. After the registration information has been verified, CAPE shall authorize the user account and requested role. All CADE Portal accounts need to be renewed at least annually.

G. PREPARED BY | H. DATE | I. APPROVED BY | J. DATE

DD FORM 1423-1, FEB 2001 PREVIOUS EDITION MAY BE USED. Page ___ of ___ Pages

Reset

Expected simulation deliverables to link to GRA should be outlined in CDRL…

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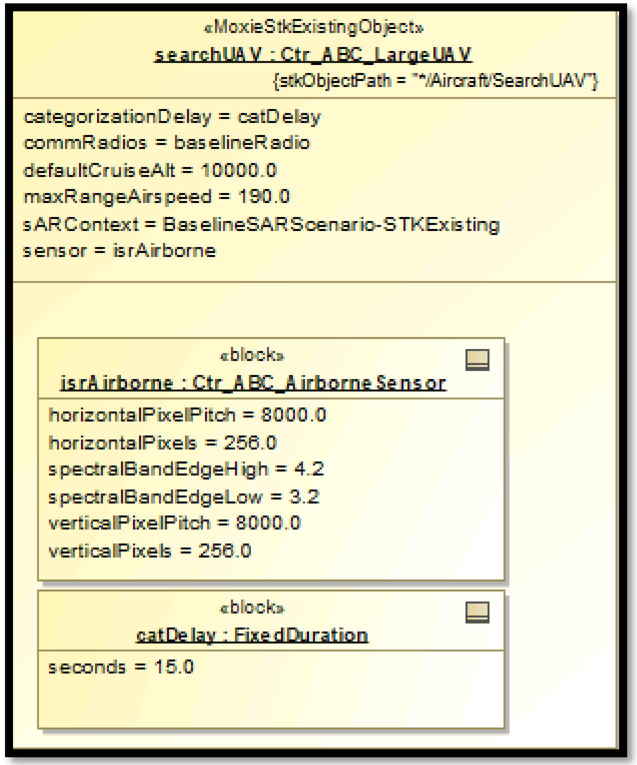
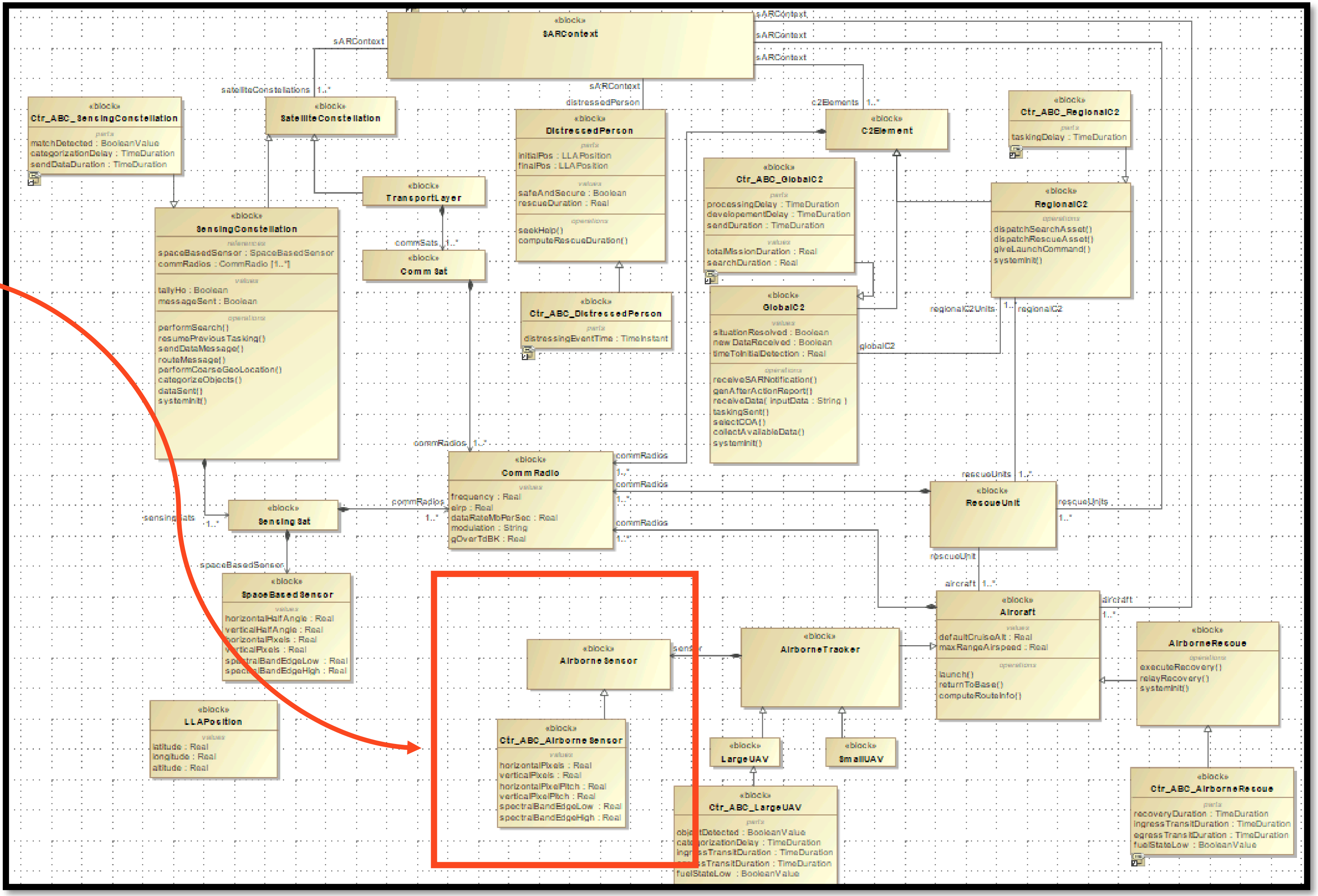
How to ***Deliver*** Simulation?

Contractor Updates GRA

- Add design component to GRA
- Update instance specifications to match inputs to simulation models





But how do we link simulation that's also deliverable?

Key Considerations for Delivering Simulation

- ✓ **How much setup/IT work is needed to *execute* the delivered simulation?**
- ✓ **How much work is needed to create the simulation artifacts?**
- ✓ **How accurately does it represent the true design?**
- ✓ **Can the simulation be executed within the mission context?**
- ✓ **What access or licensing is needed to execute simulation?**
- ✓ **How much contractor IP is exposed?**

The right answer is situational, hence the need for CDRL writing to request the right format of simulation delivery

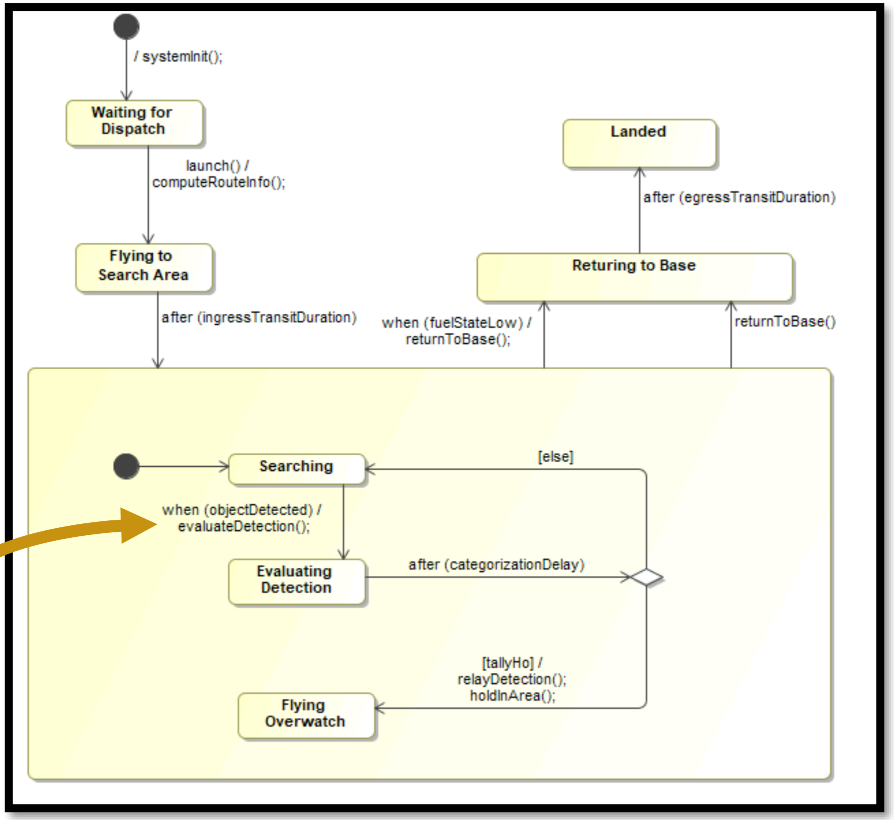
Option 1 – Component Delegates Executed through State Machines

- Integrate added model into state machines or behavior diagrams
- Ansys BEE is simulation engine, but could use API from any vendor tools
- Behavior must be defined via script delegates

```
public void evaluateDetection() {
    mSimLog.info( s: mTimeProvider.getCurrentTime().toIso8601String() + " -- AirborneTracker.evaluateDetection");
    //Get all the objects we could be searching for, look for active access between sensors and each
    //of the objects we could be looking for.  If access exists, check to see if that object is the tgt.
    ArrayList<IAgStkObject> searchForObjects = getViableSearchForObjects();

    for (IAgStkObject searchObject : searchForObjects) {
        Interval<MoxieTime> accessInt = new Interval<>(mTimeProvider.getCurrentTime(), mTimeProvider.getCurrentTime().addSec
        if (mStkToolbox.computeAccess(mAirborneTracker.getChildren().getElements(AgESTKObjectType.E_SENSOR).get(0), searchOb
        {
            mSimLog.info( s: "Found Access between: " + mAirborneTracker.getChildren().getElements(AgESTKObjectType.E_SENSOR)
            if (searchObject.getInstanceName().startsWith("Downed"))
            {
                mSimLog.info( s: "Found this distressed person named: " + searchObject.getInstanceName() + " with sensor " + 
                tallyHoProperty.setValue(true);
                mDistressedLat = DataProviderExecutor.executeSingleResultAsDouble(searchObject,  dataProviderPath: "LLA State/Fixe
                mDistressedLon = DataProviderExecutor.executeSingleResultAsDouble(searchObject,  dataProviderPath: "LLA State/Fixe
                sARContextProperty().getValue().refinedSearchStopTimeProperty().setValue(mTimeProvider.getCurrentTime().getD

            }
        }
    }
```

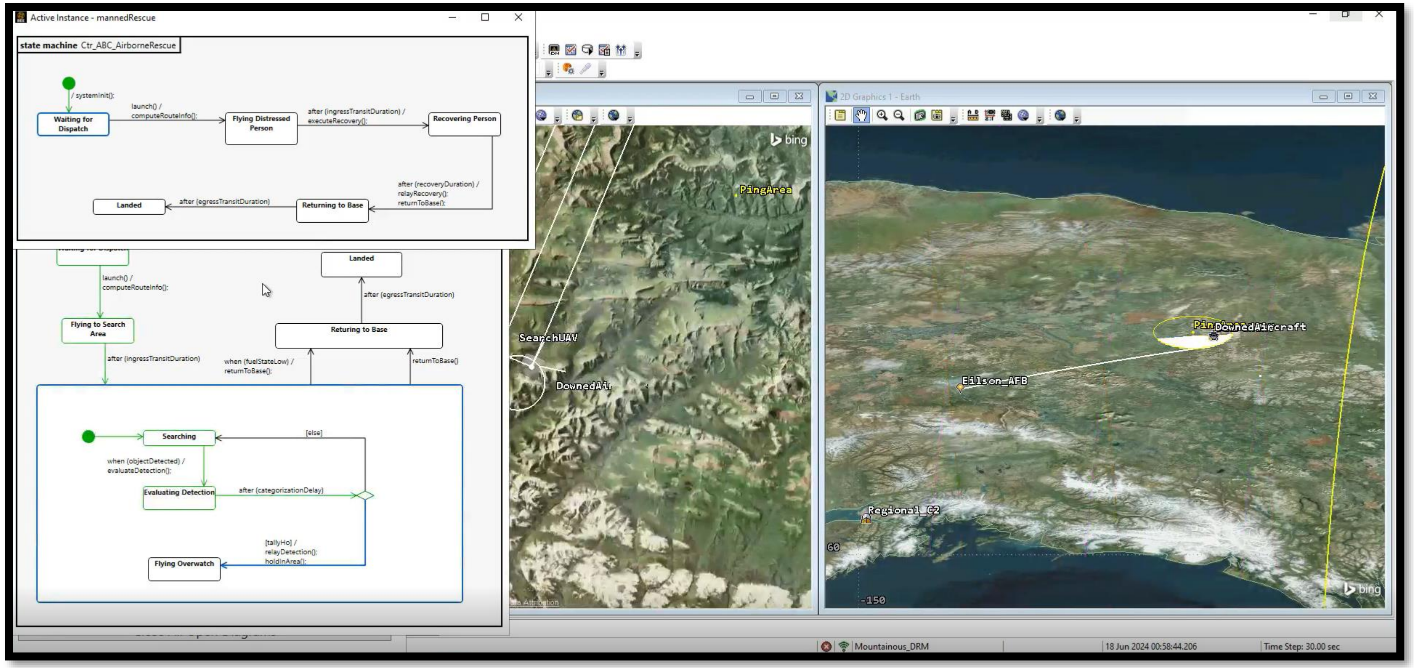


Ansys Behavior Execution Engine

Option 1 – Component Delegates Executed through State Machines

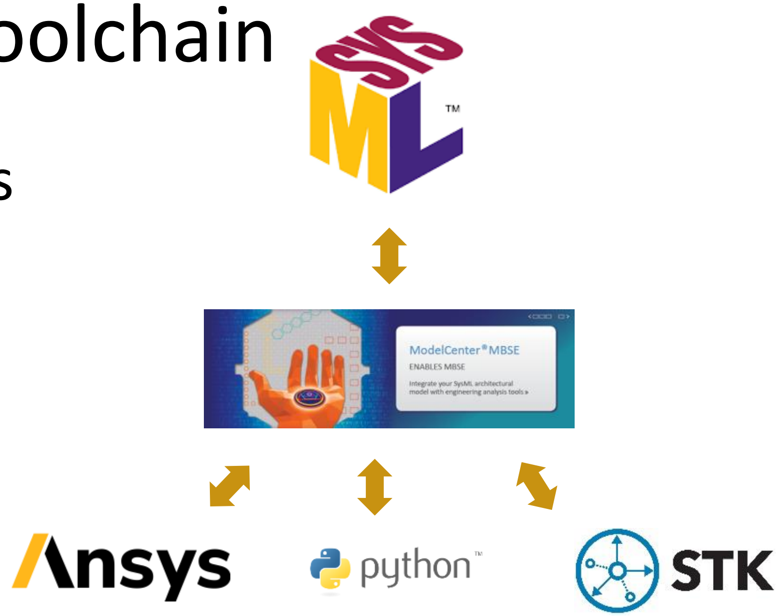
- Pros
  - Full engineering simulation
  - Can use performance-based model
    - Don’t have to expose full design
  - Integrated directly into SysML
  - Built into existing GRA
- Cons
  - Access/licenses required for all tools
  - Could be too complex for systems with simple behavior or relationships

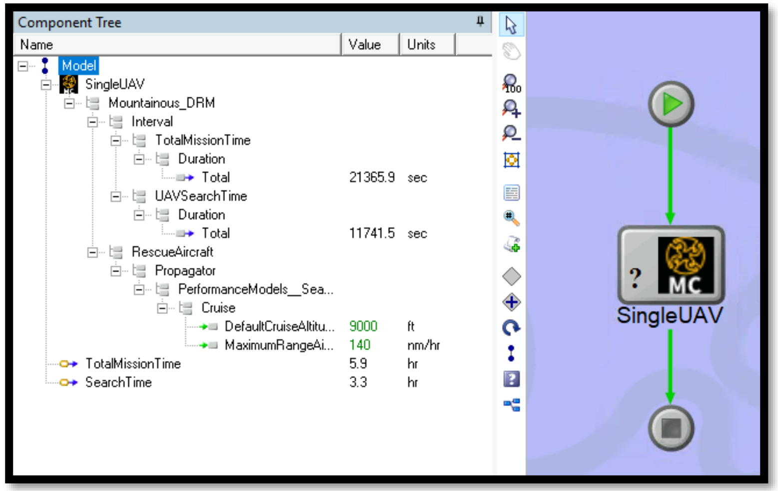
- CDRL Considerations
  - State machines must be written and delivered for all components (GRA)
  - Delegate code must be delivered



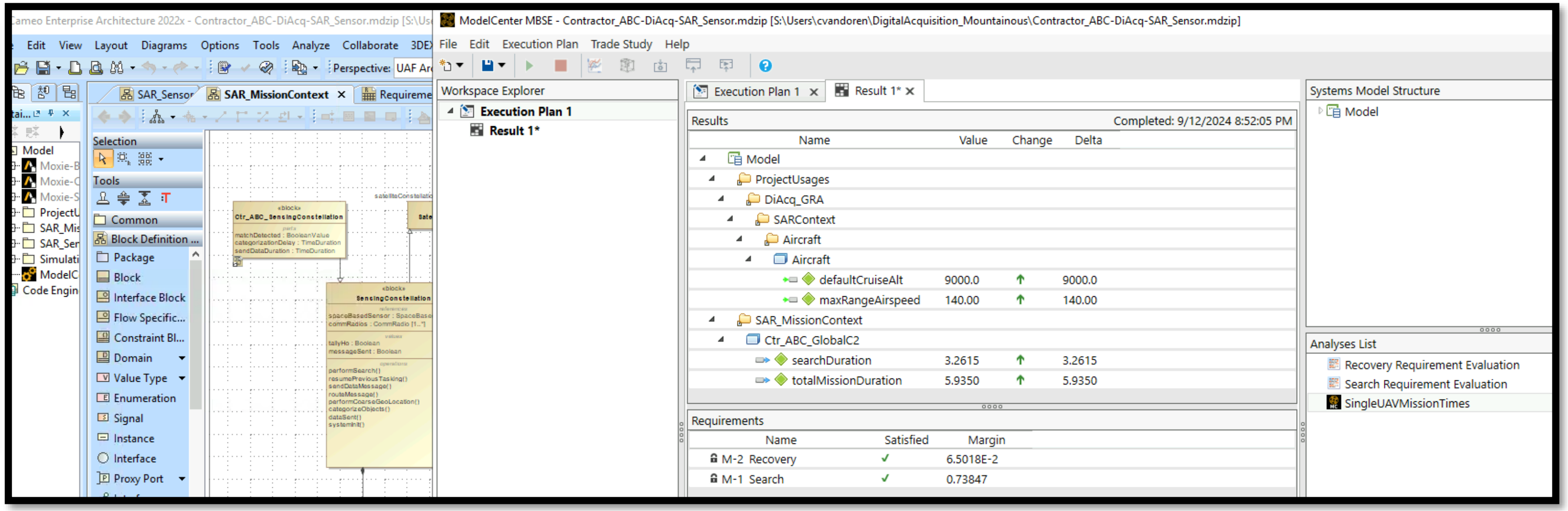
Option 2 – Parameterized Models through Toolchain

- Create toolchain via APIs or existing ModelCenter plugins
  - Inputs perturbed, run through actual simulation tools, mission outcomes re-simulated with full fidelity
- Design tool that can then be shipped as a 'deliverable'
- Script components, ROM's, FMU's can be part of chain





Ansys ModelCenter MBSE



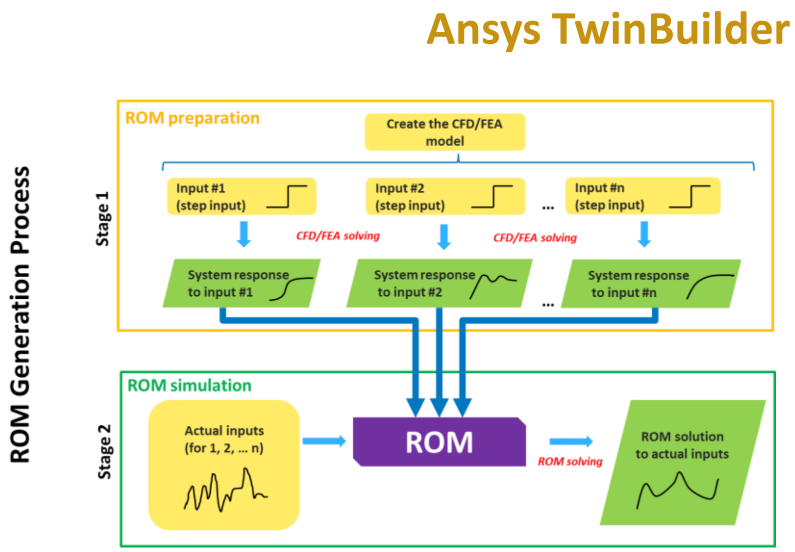
Option 2 – Parameterized Models through Toolchain

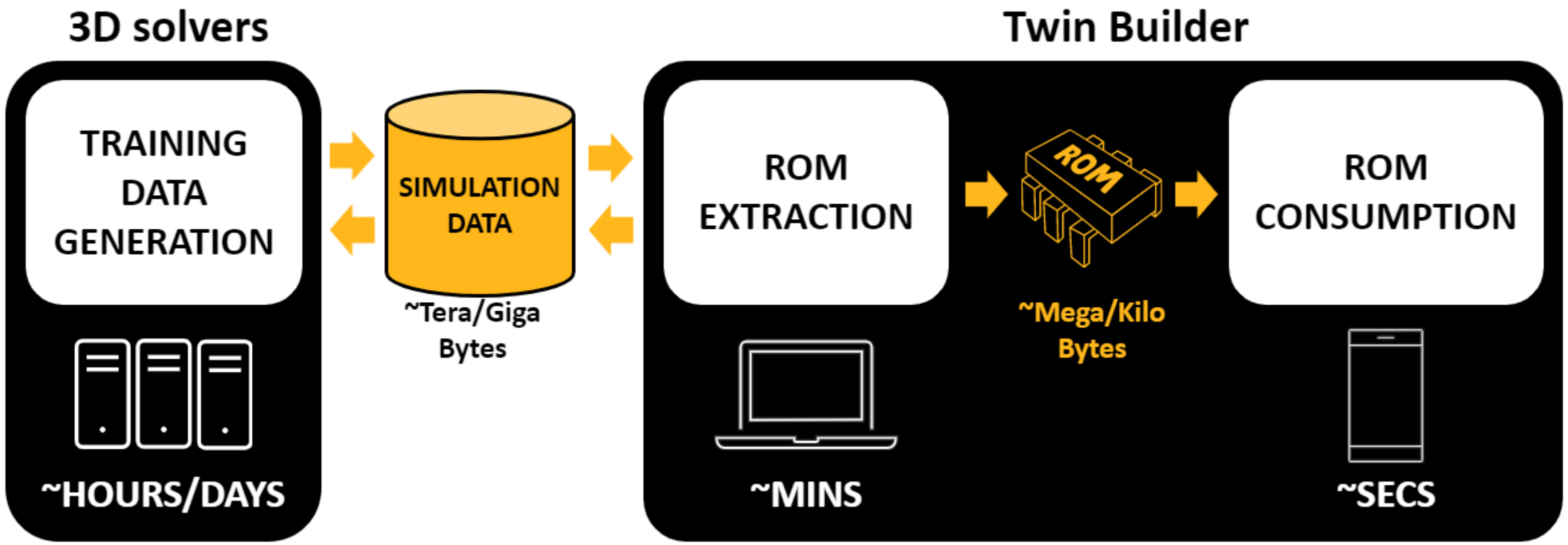
- Pros
  - Full engineering simulation
  - Scripting allows for any tool
  - ROMs, FMUs, blackbox simulations
- Cons
  - Access/licenses required for all tools
  - Rigid workflows, IT work required

- CDRL Considerations
  - “Blocks” are individual tool scripts with input/output
  - Top level workflow must be provided with inputs/outputs exposed
  - Workflow can either be executed alongside SysML or integrated through ModelCenter MBSE

Option 3 – Reduced Order Models (ROM)

- Simulations are run to fully cover the operational envelope of the system
- ROM (or ROMs) are response functions fit to output data abstracting away simulation
- Intermediate correction models can be fit to reconcile delta between ROM and sim
- ROMs are exported as FMUs or in containers not requiring specific tools to execute





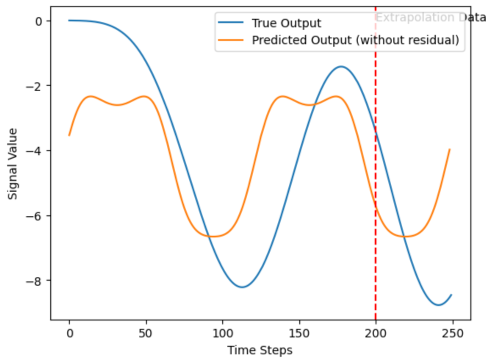
Option 3 – Reduced Order Models (ROM)

- Pros
  - Simple, easily executable
  - No additional licenses needed on acquisition side
  - Protects IP for contractor

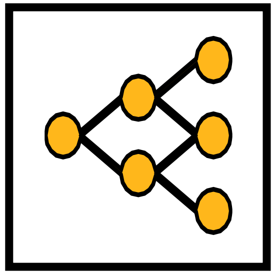
- Cons
  - Large data repository required to create
  - Opaque to acquirer, limited context on results
  - Only valid within bounds of the training data

- CDRL Considerations
  - Specify the export format (FMU, container, etc.)
  - What inputs must be exposed to be able to evaluate mission cases?

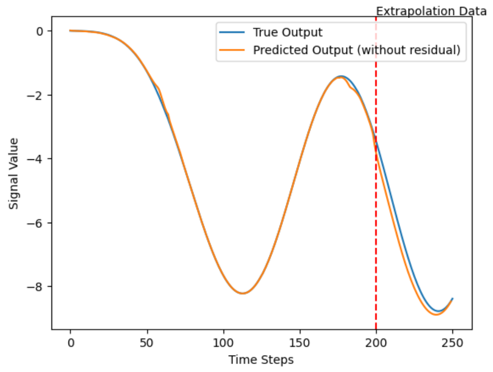
Actual Behavior



Correction Model

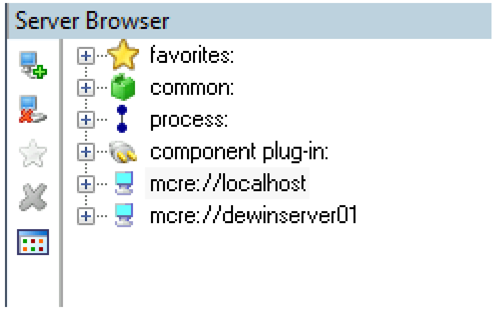


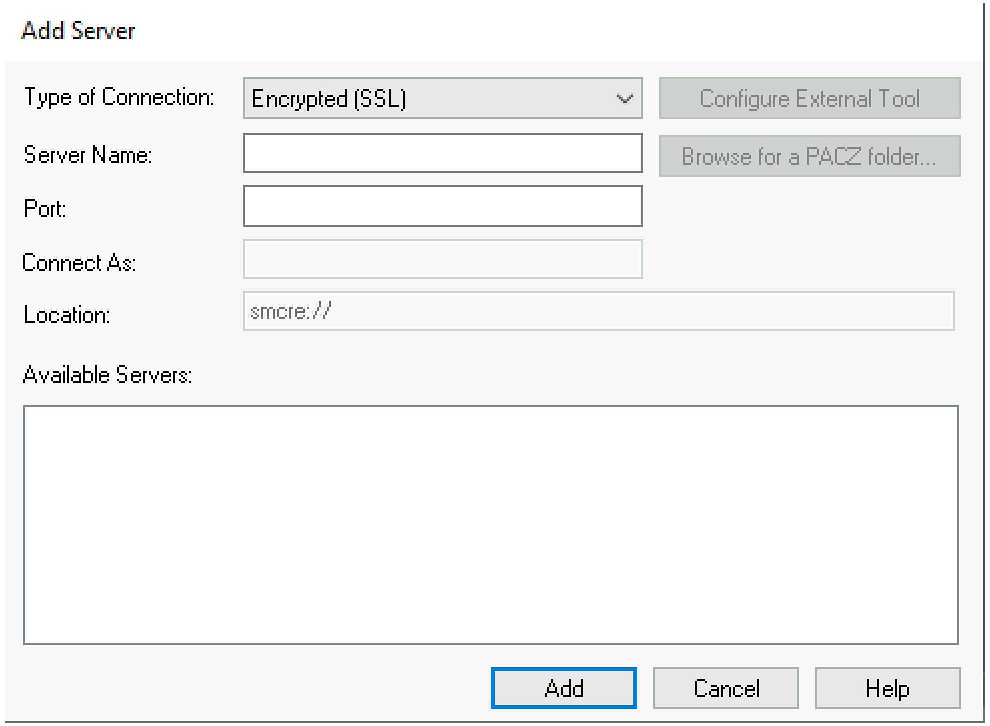
Physics Model + Correction



Option 4 – Contractor Hosts Executable

- Executable models stay within contractors network/environment
- Acquisition office can ping executable models with known inputs/outputs
- Ansys ModelCenter can chain together tools from multiple remote sources with tools locally as well
  - Alternatively, models can be FMUs or other executable and pinged directly
- Potentially contractor can even host larger simulation environment which acquirer can log into





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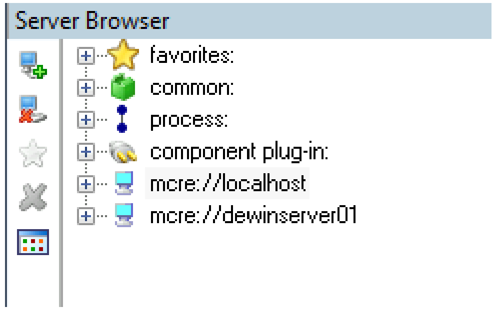
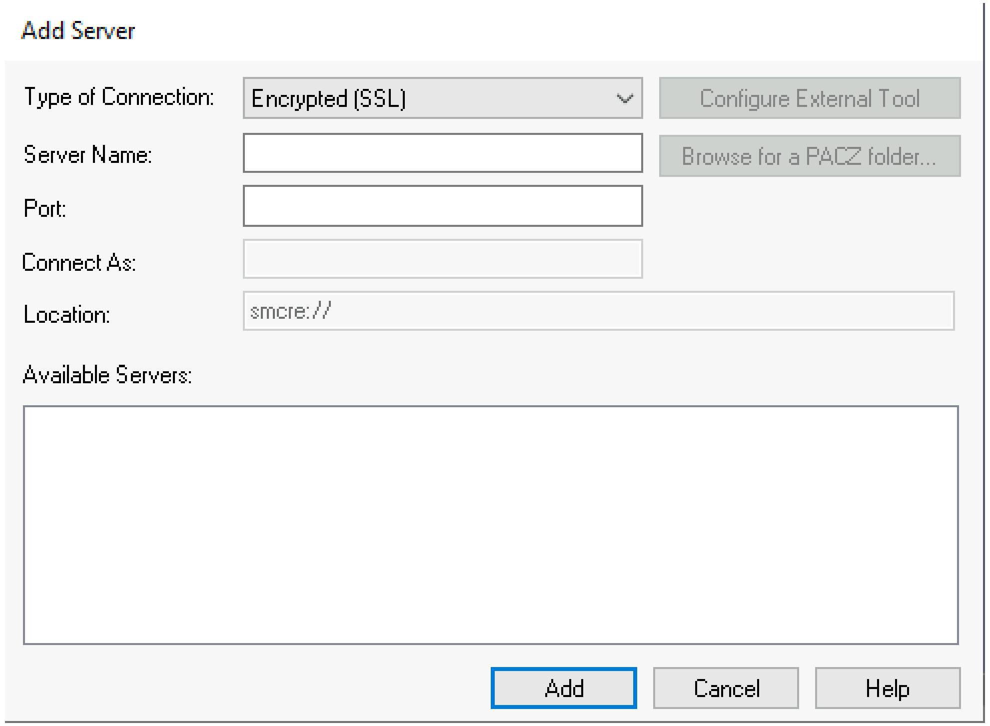
Option 4 – Contractor Hosts Executable

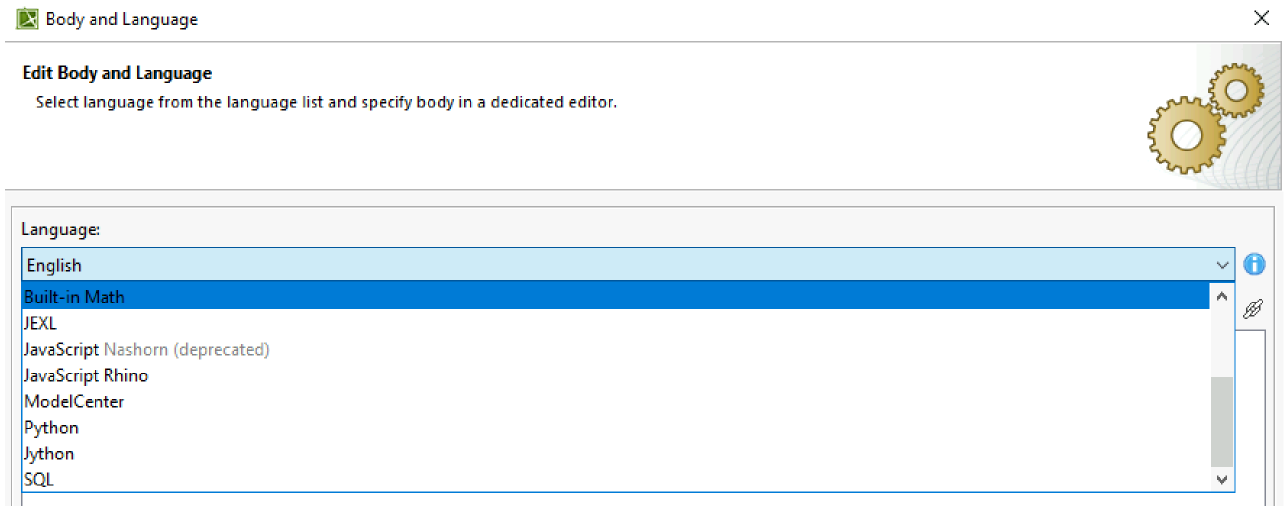
- Pros
  - Protects contractor IP while allowing full simulation
  - Acquiring office can pull together multiple contractors models
- Cons
  - Large IT workload
  - Contractor has to expose network ports or setup cloud environment externally
- CDRL Considerations
  - Format and connection type must be explicitly stated
  - Inputs/outputs for model defined

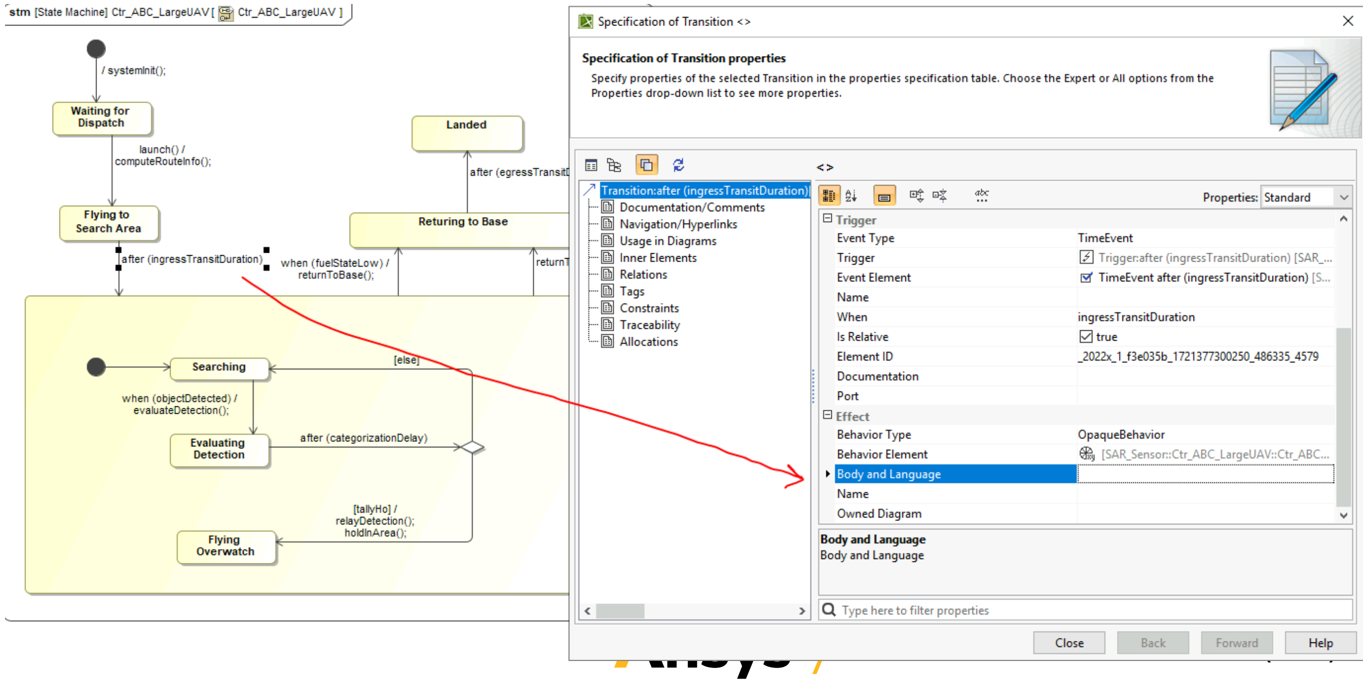




Option 5 – Scripts through Opaque Expressions

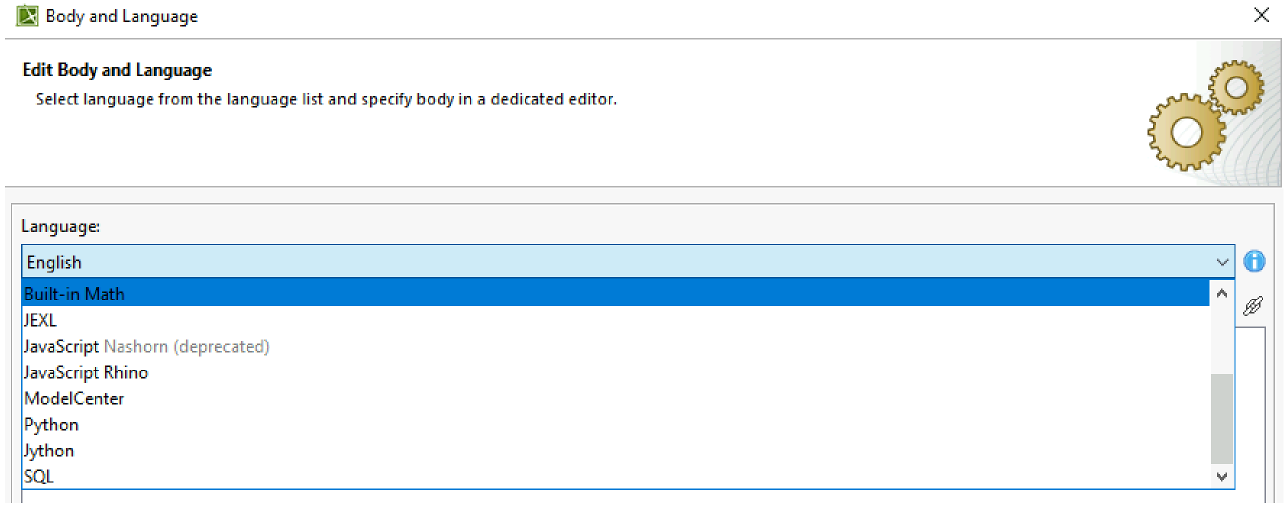
- Add state machines to existing GRA
- To execute model, opaque expressions call MATLAB, Java, etc. scripts
- Theoretically these scripts can reach out to any APIs, ROMs, etc.
  - Large scripting effort
- Requires all underlying physics to be embedded in scripts

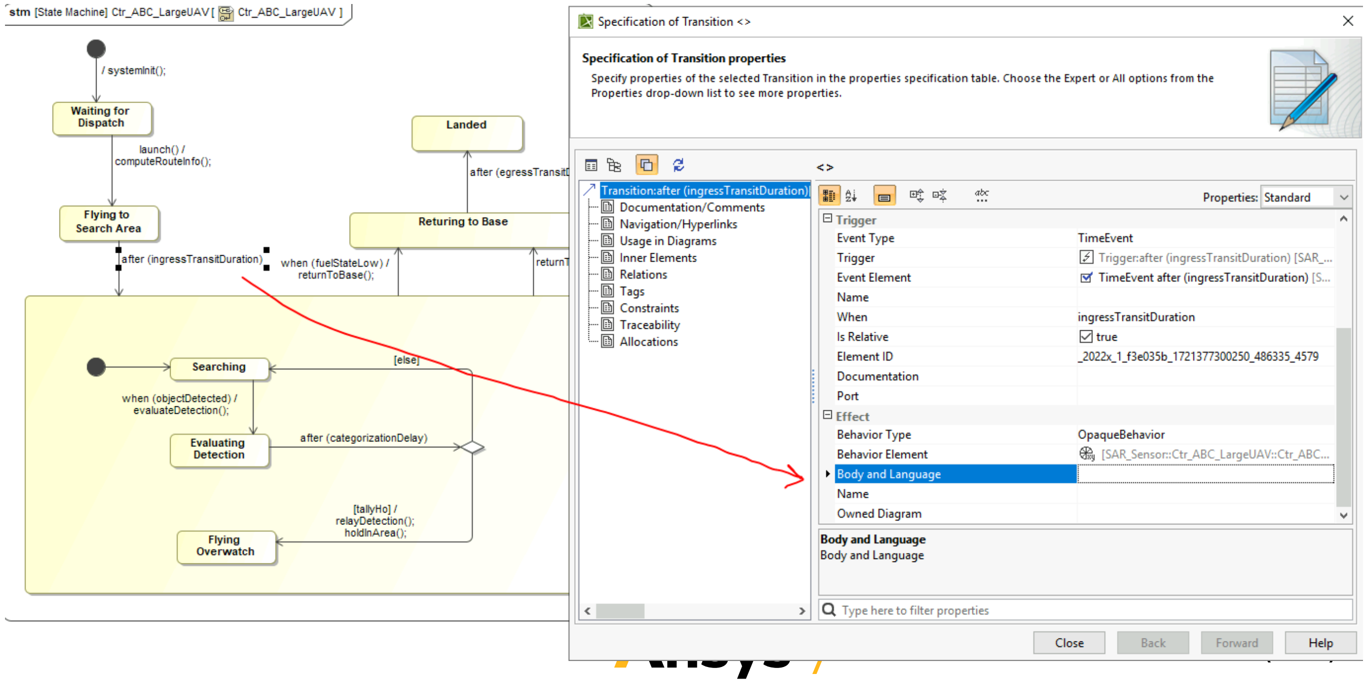




Option 5 – Scripts through Opaque Expressions

- Pros
  - Very flexible via scripts
  - No additional licenses (outside of Cameo and any scripting languages)
- Cons
  - Full performance must be coded
  - Scripts are rigid, large workload to amend models
- CDRL Considerations
  - Language options
  - GRA state machines must be amended and delivered for new components





Option 6 – Deliver Original Simulation Content

- Final executable models are delivered to the acquisition office
- Simple components of overall acquisition
  - Cost models, link budgets, transfer functions etc.
- Gives full context to the acquisition office however IP is exposed
- Not feasible for large designs with many tools
  - Cost prohibitive
  - IT prohibitive
- Compiled code in native OS languages can be executed with very little setup

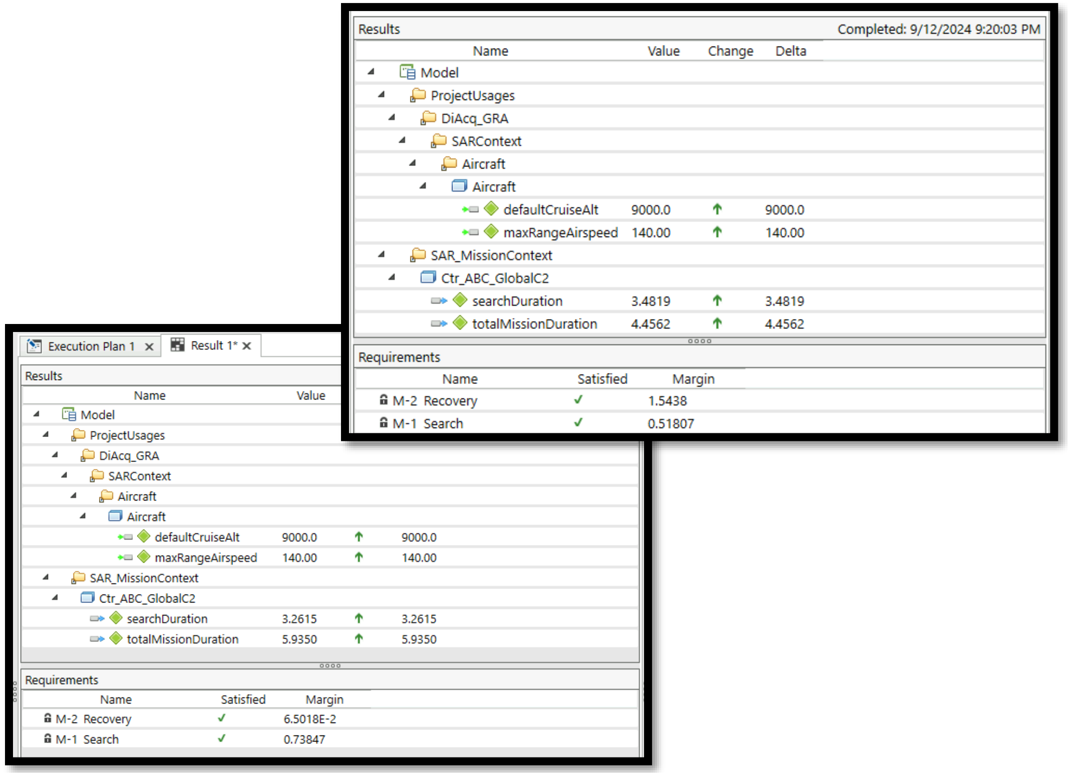
Option 6 – Deliver Original Simulation Content

- Pros
  - Full simulation fidelity
  - Full context available to acquisition office
  - No additional time on contractor side to "create" deliverables post-design
- Cons
  - Licenses required
  - No IP obfuscation
  - Non-trivial time to learn and then execute models
- CDRL Considerations
  - Tools used for models specified
  - Types of simulation files/formats specified
  - Guide for executing models from raw design tools

Acquisition Office Process

- Receive Contactor proposal artifacts
  - SysML Model
  - Data showing requirement satisfaction
    - Defined by CDRL
  - Simulation capability
    - Defined by CDRL (options previously shown)
- Compare analytical results
  - Execute models from both contractors, compare direct mission performance metrics
  - Compare cost and delivery estimates from both contractors
  - Perturb model inputs and understand design behavior under corner cases
- Make an informed decision

Contractor 1



Contractor 2

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Example Use Case

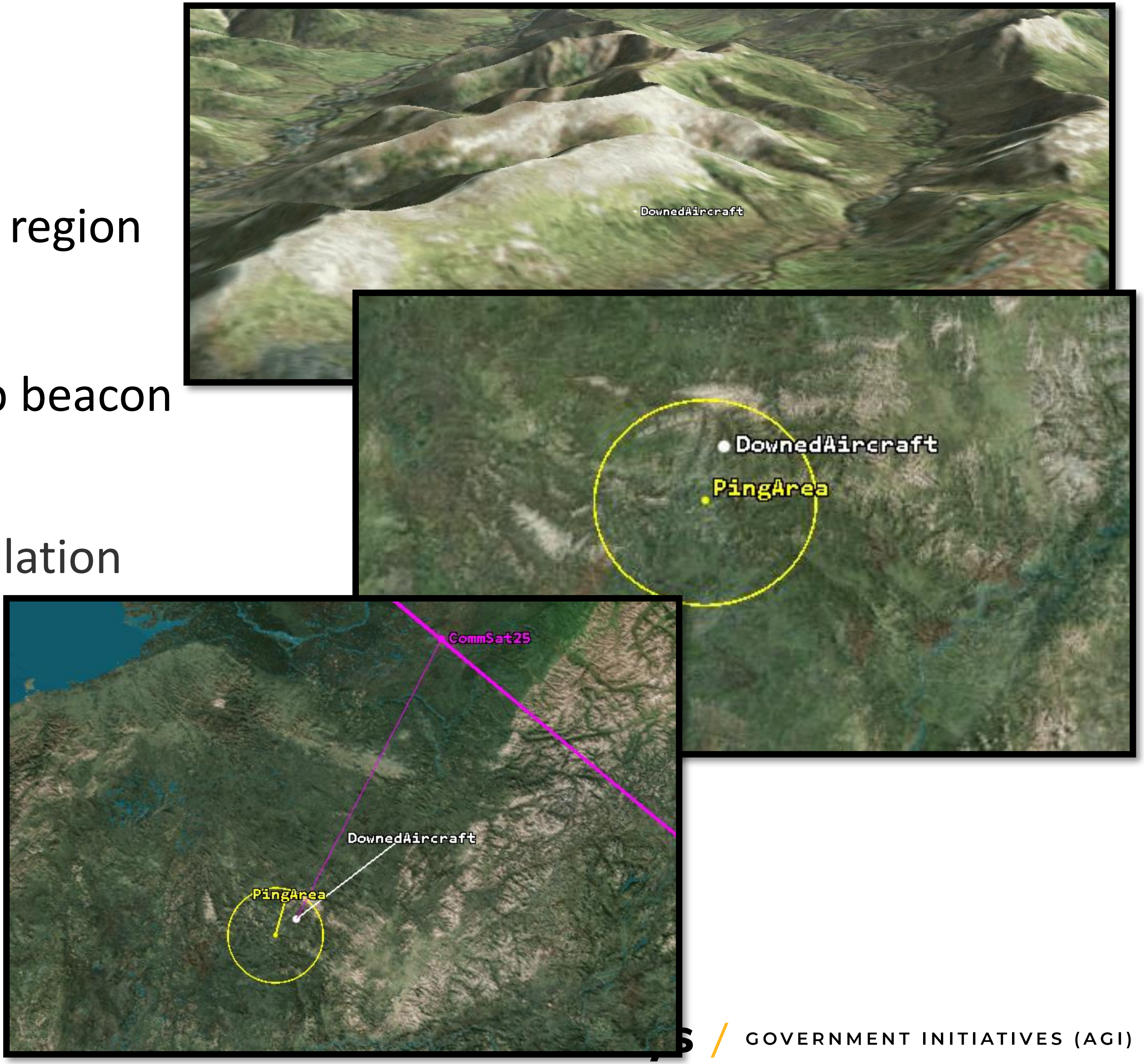
Simulation Based Use Case

- Acquisition office releases RFP for new airborne search and rescue optical sensor
  - Requirements on mission performance and cost/weight etc.
- Many sample missions included in the request
  - Multi-terrain and condition performance
  - Choice of platform depends on weight and performance of sensor
- Two primary contractors bid ***(with design choices that effect the rest of the system)***
  - One proposes singular large, powerful, expensive system
  - Two proposes lighter, cheaper sensor that can be replicated easily

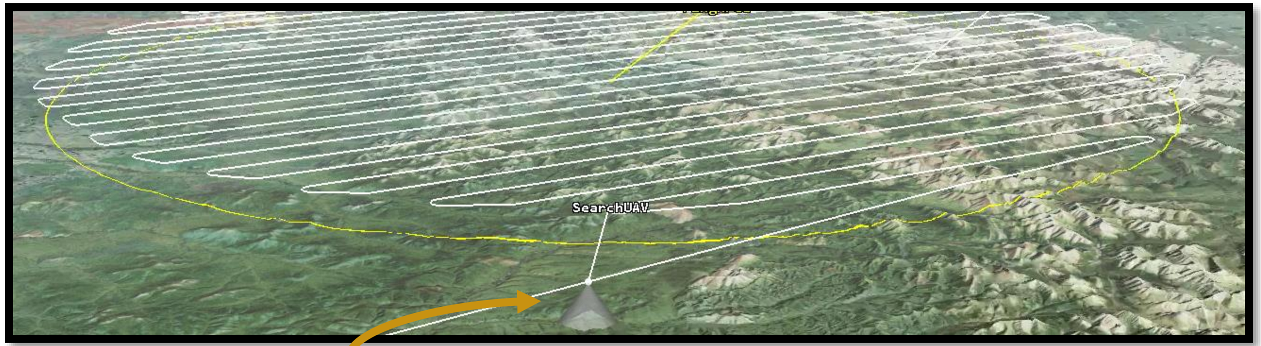
Let's look at one example mission...

Example Mission

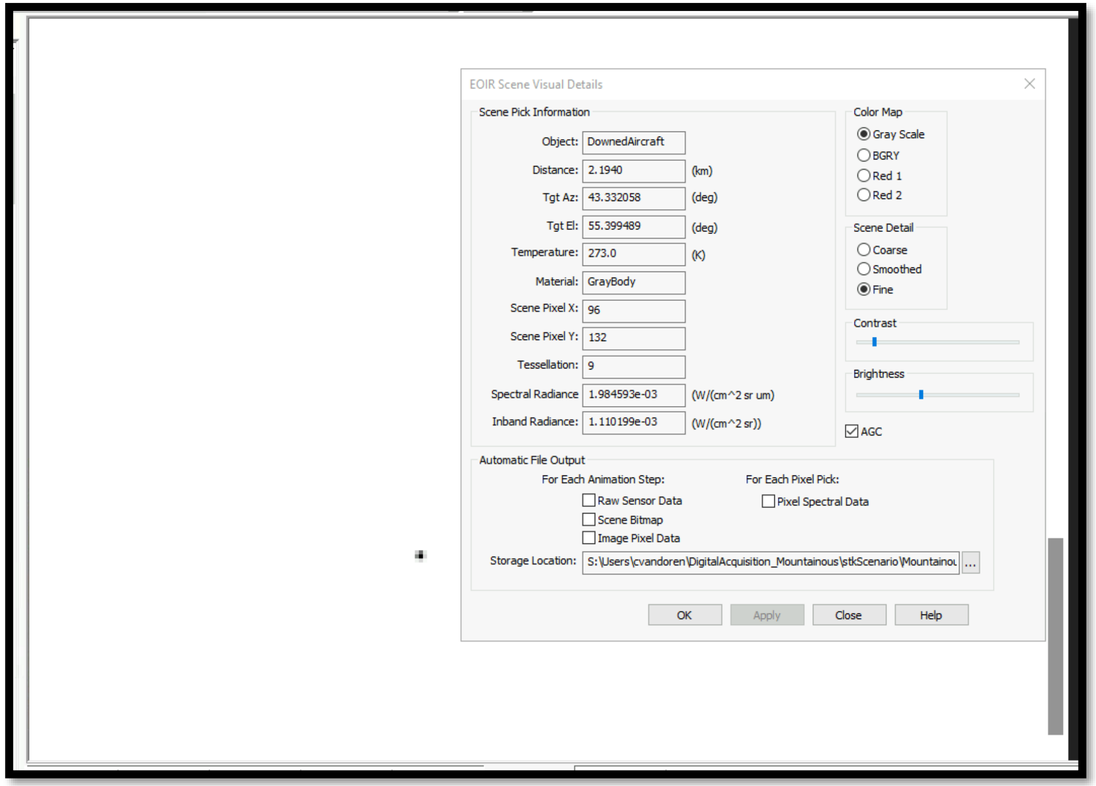
1. Aircraft is downed in mountainous region
   - Starts emitting distress beacon
2. Overhead sensing satellite picks up beacon
   - Determines approximate location
   - Alerts global C2 via satellite constellation
3. Global C2 transmits search region to regional C2



Example Mission cont.



4. Regional C2 dispatches search UAV **w/ proposed optical sensor**
   - In one case single higher, faster UAV in other case multiple smaller UAVs
5. Optical sensor picks up downed aircraft
   - Search UAV goes to holding pattern and transmits coordinates to regional C2
6. Regional C2 dispatches rescue team
7. Downed passenger recovered and returned to base



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Delivery Considerations for Use Case

1. Component (sensor system) is going to be part of a larger system (UAV)
2. Detailed design will include complex physics
   - Would be difficult to script an equivalent
3. Sensor component will impact mission outcomes based on sensing behavior
4. Many inputs required to determine sensor detection performance
   - Lighting, geometry, sensor physical characteristics, sensor pointing

So how should we deliver such a design?

Component delegate simulation with full fidelity? Sensor ROM delivered and easily executable?

Conclusions

- ✓Ansys software can enable simulation ***directly against SysML structures***
- ✓Without the ability to execute simulation ***on both sides***, "digital" deliveries are more efficient but no more useful than paper acquisition
- ✓Each requirement has different simulation needs, we must ***allow for flexibility in data*** delivery if the results are meant to be reproducible (i.e. reduce pre-post processing)

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