ASCENT Project 061

Noise Certification Streamlining

Georgia Institute of Technology

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Cost Share Partners: Boeing, Bell, Gulfstream, Rolls-Royce

Industry Partners: Boeing, Bell, Gulfstream, Rolls-Royce, Embraer, Cessna/Textron, De Havilland Canada

Objective:

Examine current noise certification procedures and identify opportunities to streamline the noise certification process in addition to recommending methodologies for building the needed flexibility to accommodate all air vehicle types

Project Goal and Benefits:

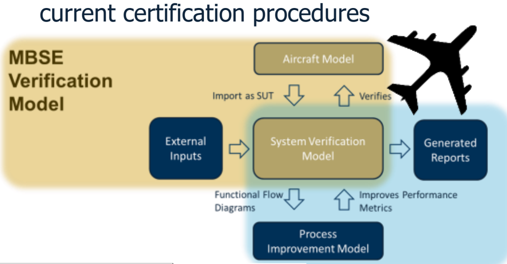
Recommendations towards a more efficient, streamlined, and flexible aircraft noise certification:

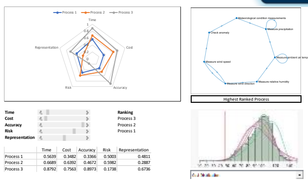
- Proposition of equivalent procedures, supported by latest technologies and hardware
- Evaluation of alternative practices through a Model-Based Systems Engineering (MBSE) model of the noise certification process (in SysML)
- Analysis techniques to support certification of future air vehicles types

Research Approach

Year 1,2: Transport Category Focus

- Develop an **MBSE-enabled noise certification model** for benchmarking current certification procedures

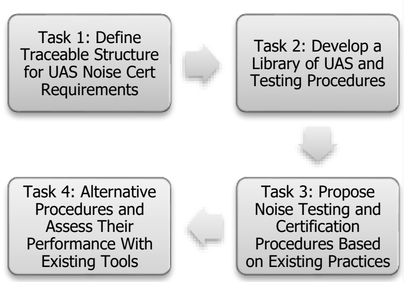




Scenario-based exploration capability to create, assess equivalency, analyze, and streamline certification process

Year 3: Rotor or small propeller-driven UAS Focus

- Explore feasibility and applicability of current ASCENT 061 models for **certification of rotor or small propeller-driven UAS**



Major Accomplishments (to date):

- Key Improvements in SysML-based **Verification Model**
- Demonstrated the **Process Improvement Model (PIM)** for streamlined certification using Markov Chains
- **Early version Visualization environment** to provide oversight on EP and regulatory compliance
- Pivot to **Rotor or small propeller-driven UAS**
- **Benchmarking** of current UAS noise certification (working with NPRM 86 FR 48281)

Future Work / Schedule (Year 3 Tasks):

- Transport Category: **Multi-scenario capability** for exploration of equivalent procedures
- Complete ASCENT 61 **UAS Noise Certification**
  - Workshops with OEMs on rotorcraft and small UAS
  - Process prototyping with guidance by NPRM 86 FR 48281
  - Testing Equivalent procedures
- Findings & Recommendations for UAS Noise Certification

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ASCENT Project 061
Noise Certification Streamlining

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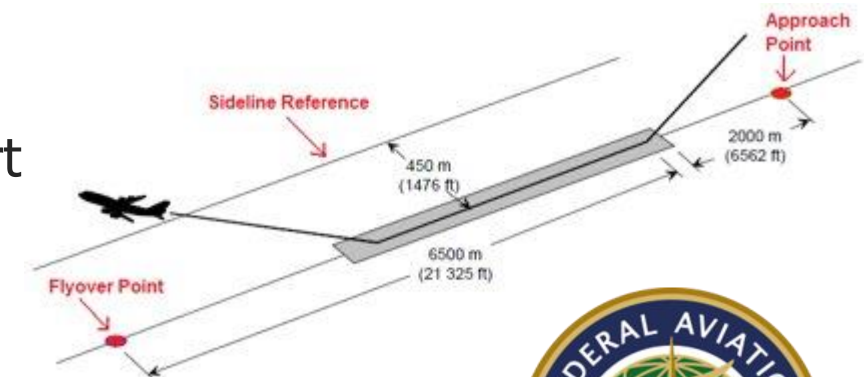
Presentation Outline

- Introduction
- Project Overview
  - The Team
  - ASCENT Project 61 3-Year Research Horizon
  - Noise Certification Framework for Transport Category and Application for UAS Configurations
- Part I: Improvements on MBSE Certification Framework for Transport Category
- Part II: Testing Framework for Noise Certification for UAS
- Conclusions and Next Steps



ASCENT 61 Team*

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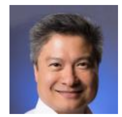

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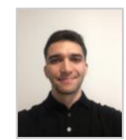

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The Georgia Tech ASCENT 61 Team would like to also acknowledge the contributions of the following past researchers: Fatma Karsten, Shireen Datta, Arnaud Ballande, Domitille Commun, Hayden Dean, Dr. Sehwan Oh and Dr. Etienne Demers Bouchard

ASCENT Project 61 Research Horizon

Objective: Examine current noise certification procedures and identify opportunities to streamline by: 1) mitigating process bottlenecks, 2)addressing complexity, risk and uncertainty 3) ensuring transparency and repeatability

Year 1 (Completed)

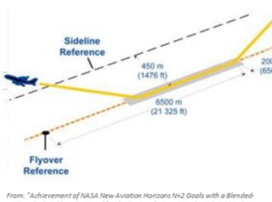
- Review **Title 14 CFR, Part 36**, (plus Advisory Circulars) to understand current regulatory framework
- Workshops with **Industrial Partners** on noise certification procedures with focus on **certification flight testing**

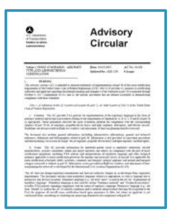
Year 2 (Completed)

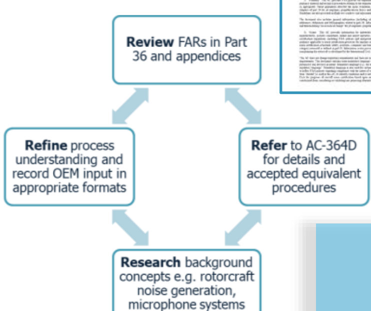
- Develop an **MBSE-enabled noise certification model** for benchmarking current certification procedures

Year 3 (In Progress)

- Formulate, simulate and evaluate **streamlined noise certification** procedures for **existing and new** aircraft types





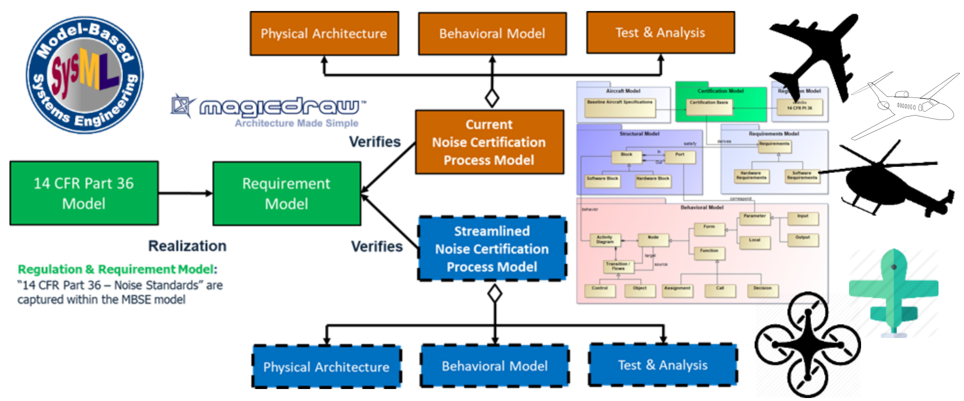


1 Flight Test Preparation
- Flight Test Plan
- Test location selection
- Schedule and resources
- Instrumentation setup
- Go/no-go conditions

2 Flight Test Execution
- Key hardware (e.g., mic)
- Data collection issues
- Track test objectives
- Airport location issues
- Coordination across roles

3 Planning & Testing
- Interactions with other Parts (e.g., 36 with 25)
- Decisions during certification
- Conformity
- New aircraft types?

4 Analysis & Reporting
- Post-test methods (data validation, etc.)
- NAC detection
- Final artifacts
- Reporting with the FAA



End Goal: Provide recommendations to the FAA in the form of equivalent procedures, supported by latest technologies/hardware, as well as analysis techniques to support certification of future air vehicles types

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Overview of Y2 to Y3 Direction: Noise Certification for UAS

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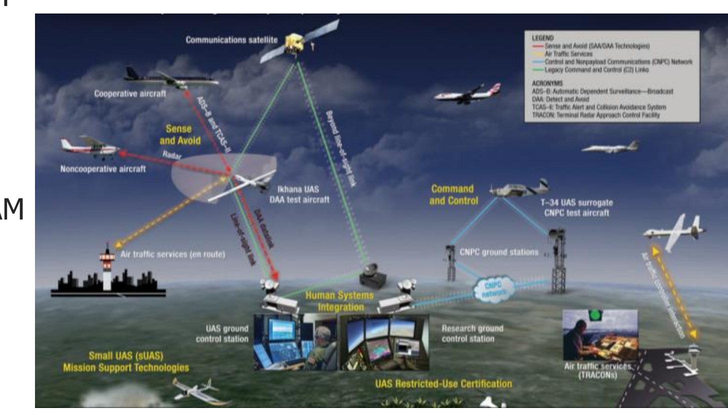
The Ask: Explore applicability of current ASCENT 061 models and analysis tools (based on transport category) for certification of rotor or small propeller-driven UAS

- **The Challenges:**
  - Large spectrum of UAS vehicles. Is our certification framework flexible to accommodate UAS?
  - No general regulations. Application on case-to-case basis. Are current testing procedures effective for UAS?
  - Assess and assist in iterating NPRMs for UAS Noise Certification Standards
  - Address UAS before UAM (where risks are higher)
- **The Opportunities**
  - Test current procedures and assess flexibility of certification framework
  - Initiate collaboration with ASCENT 077 researchers (PennState – Led by Prof. Eric Greenwood)
    - "Measurements To Support Noise Certification For UAS/UAM Vehicles And Identify Noise Reduction Opportunities"
    - Exchange of data and methods for noise measurements



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Coordination: Parallel ASCENT Work

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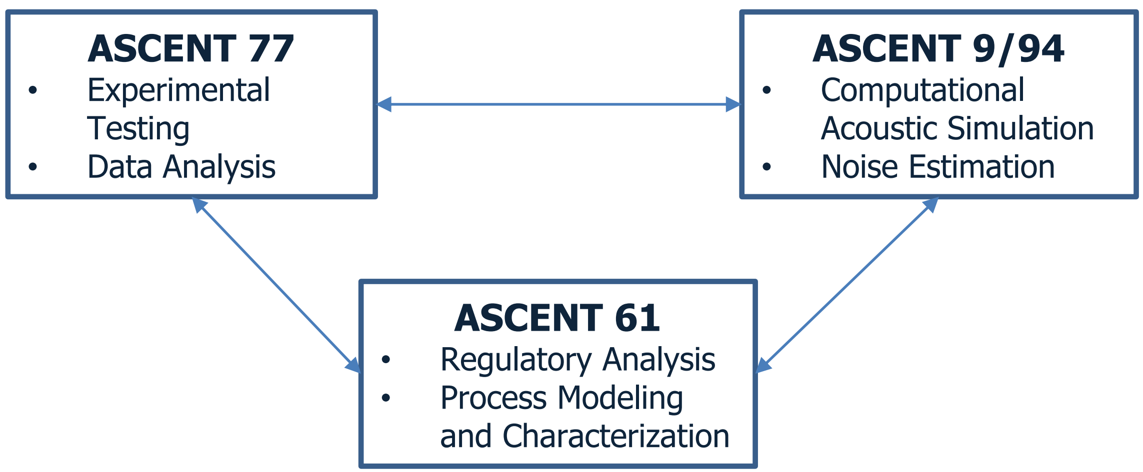
Currently there are 3 related, but unique ASCENT research efforts related to UAV/UAM noise.

- ASCENT 77 *Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction* Penn State University
- ASCENT 9/94 *Geospatially Driven Noise Estimation Module* Georgia Tech (ASDL)
- ASCENT 61 *Noise Certification Streamlining* Georgia Tech (ASDL)

To preclude "mission creep" into another projects remit, the Project 61 team is coordinating on a regular basis with Project 77 and Project 9/94 team members

- Data sharing: Experimental test data provides real world input to Noise certification modeling
- Comparison of mission profiles, certification profiles, and experimental testing field geometry Improves certification demonstration conditions



Part I: Updates on MBSE-enabled Certification Process Assessment and Improvement Framework

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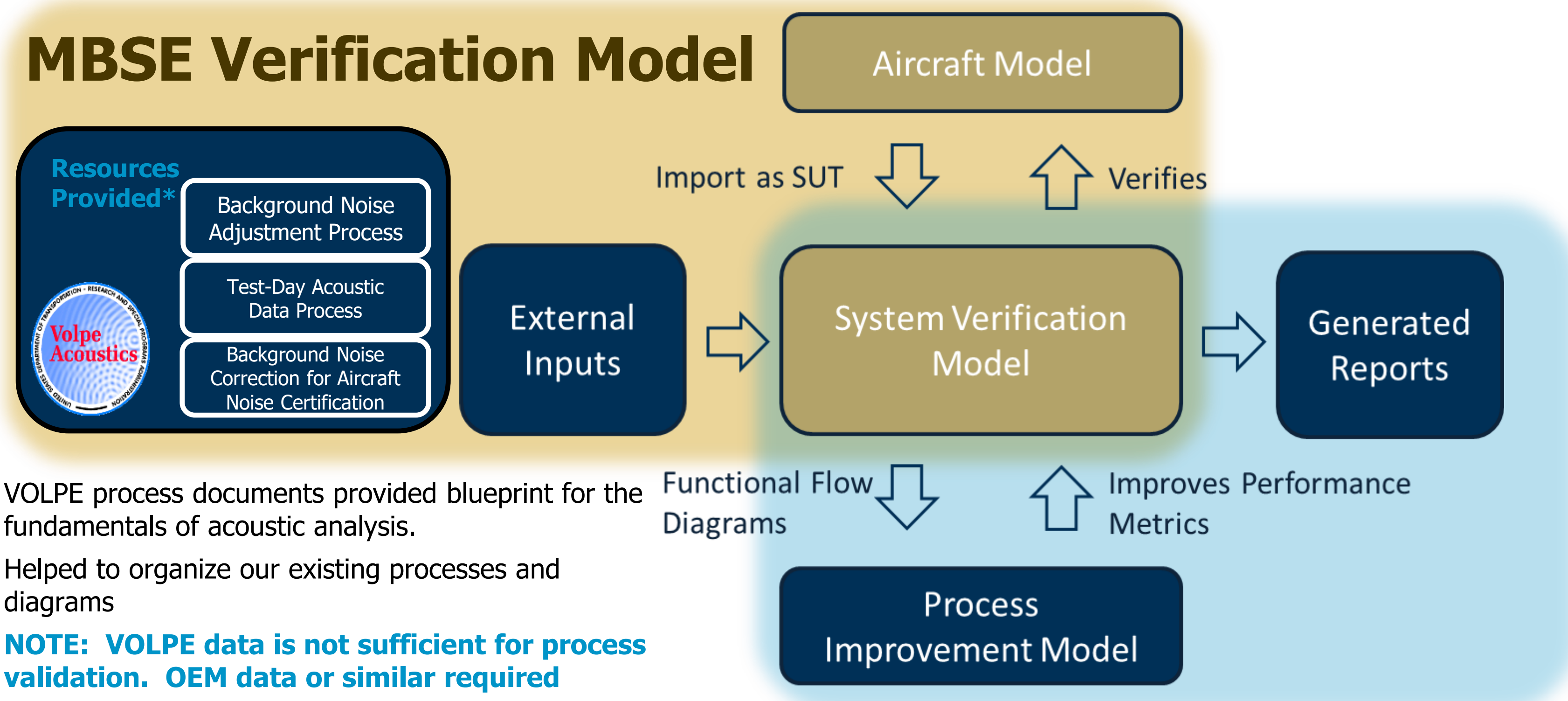
Goal: Evaluate that potential alternative testing, measurement and analysis methods are acoustically conforming to regulatory standards

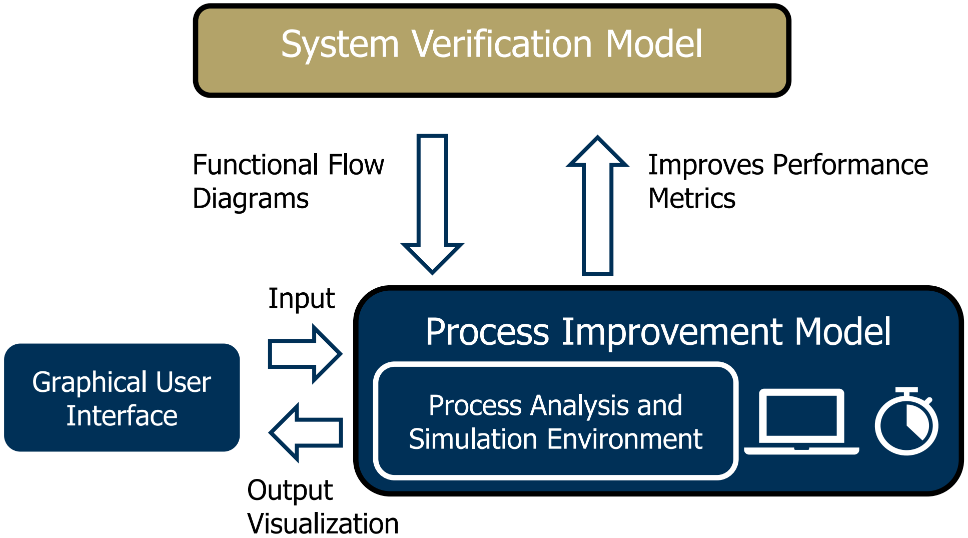


- VOLPE process documents provided blueprint for the fundamentals of acoustic analysis.
- Helped to organize our existing processes and diagrams
- **NOTE: VOLPE data is not sufficient for process validation. OEM data or similar required**

Next Step: Process Improvement Model (PIM) the tool set:
Intended to provide quantitative guidance for process modification

VOLPE Resources*: "Validation Protocol for Digital Audio Recorders User in Aircraft-Noise Certification Testing" [2010]
"Audio Recording & Analysis System Validation Checklist" [2018]
"Test Data Acoustic Data Process" [2003]
"Background Noise Adjustment Process" [2003]

Process Improvement Model (PIM)



The Process Improvement Model (PIM) is designed to represent and analyze the certification process for noise

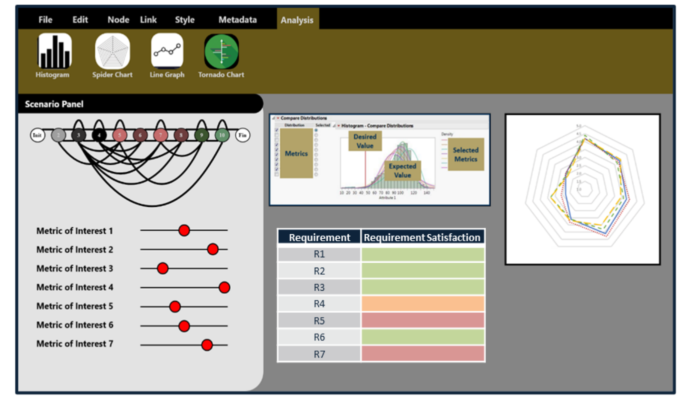
What does it do:

- Represents disjointed processes as a single chain of events
- Performs analysis of event chain

How does it do it?

- **Graph theoretic approach** to assess the efficiency, robustness, and complexity of the process chain
- **Monte Carlo Markov Chain Simulation (MCMC)** to analyze the performance of the events chain

Graphical User Interface for Process Specification



- Provide **visual representations** of the process analysis outputs
- Provide **critical metric information** obtained from the process analysis
- Assess the **equivalency of a procedure** to standard regulatory practices

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Evaluation Techniques in PIM

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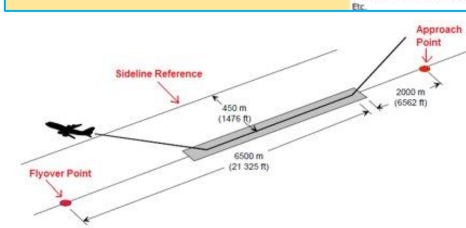
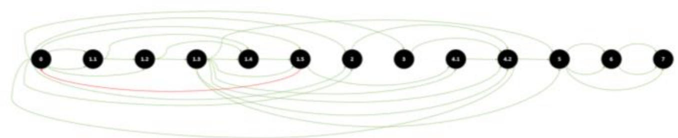
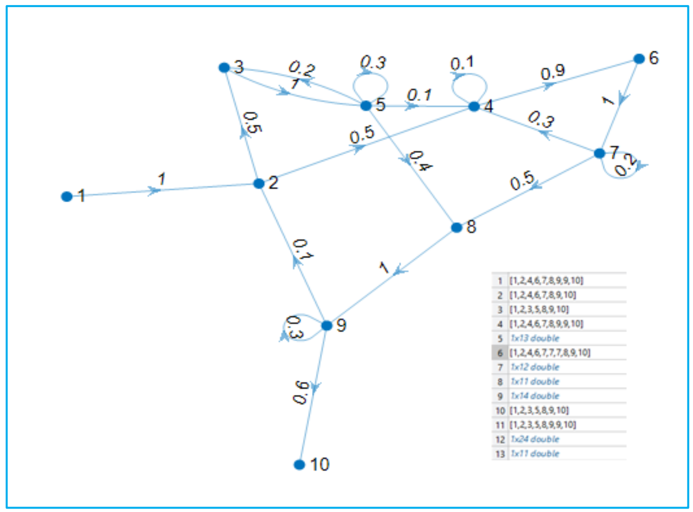
Define Test Day Data Process: Tests, recordings and SPL Analysis

Represent Process as Event Chain and Graph Model and Analyze using Graph Theory

Analyze Process through Probabilistic MCMC Simulation



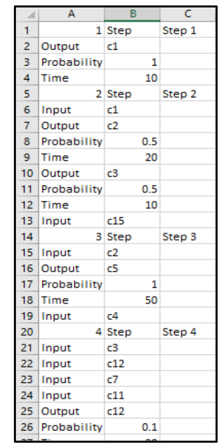




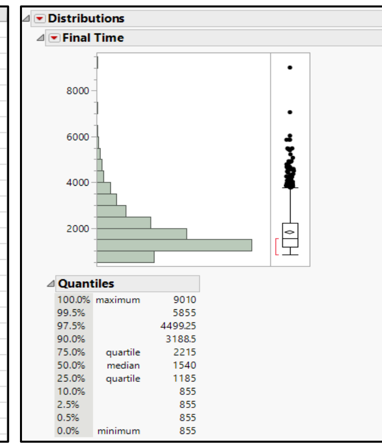
Goal: Analyze complexity of the process as well as identifying potential bottlenecks

Use a Weighted Directed Graph:

- Each node represents a step in the process
- Edges represent transitions between steps
- Progression through the steps is represented by probabilities and parameters at each step



	A	B	C
1	1	Step	Step 1
2	Output	c1	
3	Probability	1	
4	Time	10	
5	2	Step	Step 2
6	Input	c1	
7	Output	c2	
8	Probability	0.5	
9	Time	20	
10	Output	c3	
11	Probability	0.5	
12	Time	10	
13	Input	c15	
14	3	Step	Step 3
15	Input	c2	
16	Output	c5	
17	Probability	1	
18	Time	50	
19	Input	c4	
20	4	Step	Step 4
21	Input	c3	
22	Input	c12	
23	Input	c7	
24	Input	c11	
25	Output	c12	
26	Probability	0.1	



100.0%	maximum	9010
99.5%		5855
97.5%		4499.25
90.0%		3188.5
75.0%	quartile	2215
50.0%	median	1540
25.0%	quartile	1185
10.0%		855
2.5%		855
0.5%		855
0.0%	minimum	855

Early “Monte Carlo Markov Chain” (MCMC) algorithm steps:

1. Start from a node
2. “Roll dice” (generate a random number)
3. Depending on the outcome, and the probability of each path, the algorithm selects the next node
4. Learning factor is utilized to update probabilities of progressing through the steps (increased probability the second time)

Tracking Metrics:

- Time and Cost for completing process
- Complexity/Uncertainty-driven error propagation

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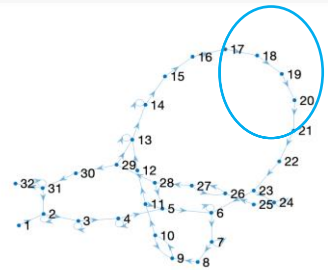
PIM Demonstration Use Case

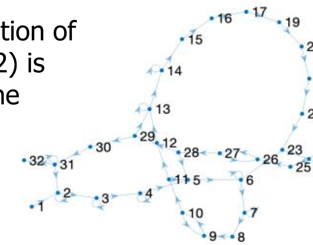
PIM demonstration on assessing a simplified noise collection/analysis process for **Waco YMF-5 propeller aircraft**

- The baseline (original) process was formulated within the PIM and executed using best* estimates for times and cost
- The simplified process removes step 18 (calculation of the second flight segment) while other steps were updated with new values to capture the updated process



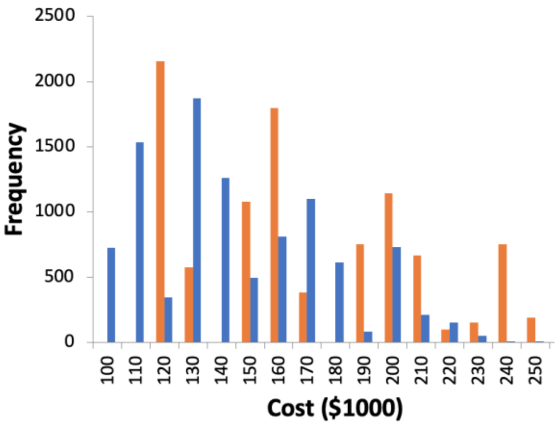
Markov Chain for original process

Step 18 (Calculation of Flight Segment 2) is removed from the process

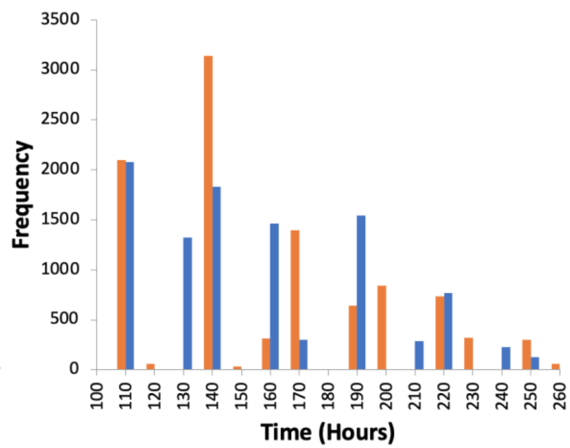


Markov Chain for reduced flight segments demonstration

Overall Cost Distribution



Overall Time Distribution



■ Original Process ■ Reduced Flight Segments

Execution of MC-based Monte Carlo analysis and comparison between baseline and simplified process

Observations

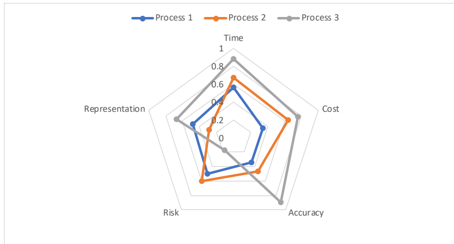
- Reduction of average process cost by 16%
- Reduction of average process time by 2%

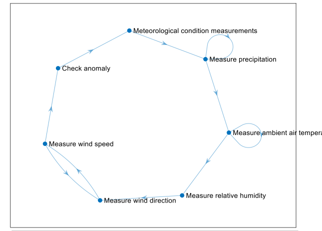
		Mean
Original	**Cost($)**	166,770
	Time(hrs.)	155
Reduced Segments	**Cost($)**	140,430
	Time(hrs.)	151

*Best estimates obtained FAA DER, referenced in the STC report on the Waco YMF-5 propeller aircraft

Conceptual Visualization Environment

Early implementation of a Minimum Viable Product (MVP) for the visualization environment



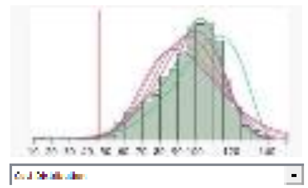


Highest Ranked Process

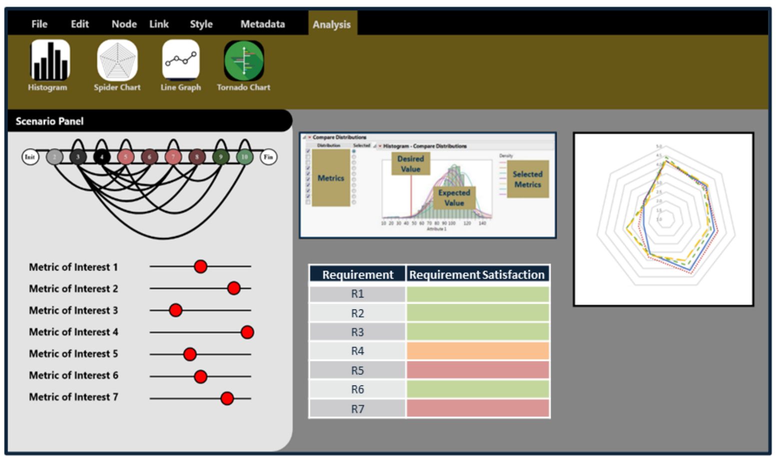
Time
Cost
Accuracy
Risk
Representation

Ranking
Process 3
Process 2
Process 1

	Time	Cost	Accuracy	Risk	Representation
Process 1	0.5639	0.3482	0.3366	0.5003	0.4811
Process 2	0.6689	0.6392	0.4672	0.5982	0.2887
Process 3	0.8792	0.7563	0.8973	0.1738	0.6736



Representation of the envisioned visualization environment



Current capabilities of the environment include:

- A spider chart to display the means of multiple metrics for multiple processes
- The highest ranked process as a chain of events
- Selection of distributions for multiple metrics
- The mean values of distributions
- Slider-bars to adjust the desirability of criteria

End Goal: An interactive and user-friendly capability to create, assess equivalency, analyze, and streamline certification process

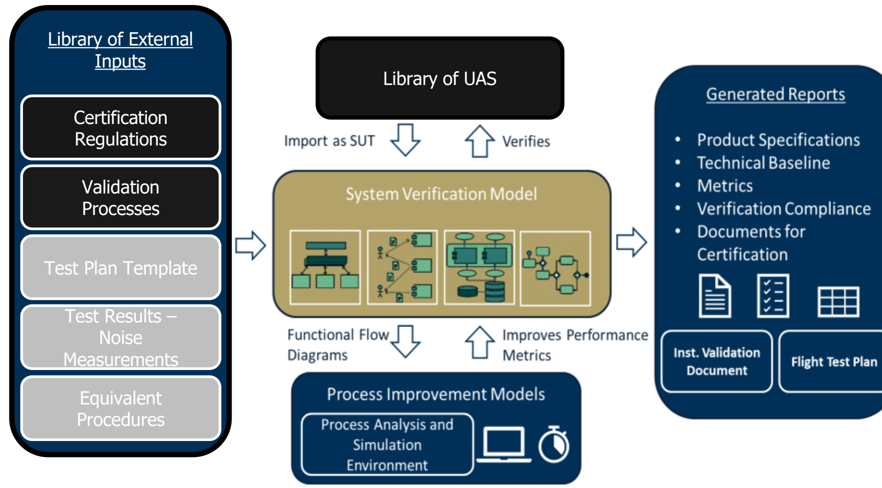
Part II: MBSE Noise Certification for UAS: Planning the framework transition process

The Ask: Explore feasibility and applicability of current ASCENT 061 models for certification of rotor or small propeller-driven UAS. **The Goals** are:

- Track and ensure traceability between regulations, testing requirements and certification procedures
- Demonstrate feasibility of NPRMs, recommend testing procedures for UAS noise certification

Observed Challenges:

- No clear regulatory framework
  - Study will rely on NPRMs, Appendices G, J, and H of CFR Title 14 Part 36
- No clear categorization of UAS
  - Study will propose criteria, e.g., weight; propeller no./type/orientation; flight envelope; max speed; operational altitude]
- No test data immediately available
  - Study will rely on test plan information, test day logs, and available/sharable noise data by ASCENT77
- No established validation process against regulation-driven requirements
  - Study will track/ensure traceability between regulations, testing requirements and certification procedures



Modified ASCENT 61 Certification Process Model for UAS

Proposed Approach & Timeline

1. Task 1: Develop a Traceable Structure for UAS Noise Certification Requirements
   Main focus for Jun-Sept 2022
2. Task 2: Develop a Library of UAS and Testing Procedures
3. Task 3: Propose Noise Testing and Certification Procedures Based on Existing Practices
4. Task 4: Develop Alternative Procedures and Assess Their Performance With Existing Tools

Task 1: Analyze Regulatory Requirements Analysis Process

Objective: Analyze proposed noise test procedure requirements for suitability to UAS category vehicles and understand sensitivity of noise to the operational flight parameters

1 Gather Requirements → **2** Gather Supporting Data → **3** Requirements Analysis

What to look for:

- Noise Level Classification
- Vehicle/Operational Classification
- Noise Metrics
- Testing Framework: Flight Profiles, SUT Configurations, Measurements

Example: Use of NPRM 86 FR 48281* for Matternet M2 (MM2) UAS seeking type certification**

Part 36 Appendix J covers alternative noise certification procedure for helicopters (under Subpart H) having a ***maximum certificated takeoff weight of not more than 7,000 Pounds***

**Matternet noise standard final rule was published in September 2022

What to look for:

- Test data and insights by the ASCENT 77 group
  - Octocopter (Tarot X8) measurements for Hover Vertical Takeoff and Landing, Flyover, Maneuvering, Approach/Climb
  - Tests conducted at varying payload weights, speeds and weather
- Academic or industrial research literature (e.g., FAA UAS BEYOND)
- Noise prediction models to generate data in support for requirements analysis

How is it performed:

Use of obtained test data and leveraging functions within the MBSE certification framework, and the following criteria:

Non-Functional

Language Quality
- Necessary
- Unique
- Unambiguous
- Clear and concise
- Singular

Functional

Procedure Feasibility
- Measurable/quantifiable
- Verifiable (e.g., Testable)
- Traceable

Technical Adequacy
- Complete
- Consistent
- Technically feasible/achievable/obtainable
- Operationally effective
- Survivable

*NPRM 86 FR 48281 (September 2021): https://www.federalregister.gov/documents/2022/09/12/2022-19639/noise-certification-standards-matternet-model-m2-aircraft
Matternet Noise Standard (September 2022) : https://www.regulations.gov/document/FAA-2021-0710-0016
[1] US Department of Defense Systems Engineering Guidebook Section 4.2.7

Example Case Study: NPRM 26(b) Feasibility

1 Gather Requirements

NPRM - 26(b): *The minimum sample size acceptable for the aircraft flyover certification measurements is **six**. The number of samples must be sufficient to establish statistically a **90 percent confidence limit that does not exceed ±1.5 dB(A).***

2 Gather Supporting Data

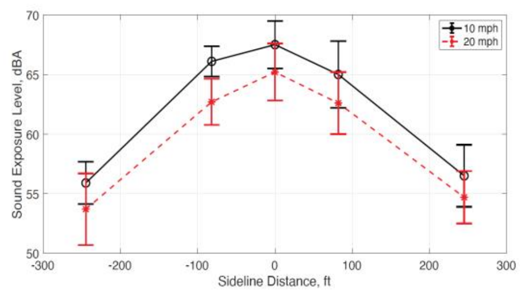


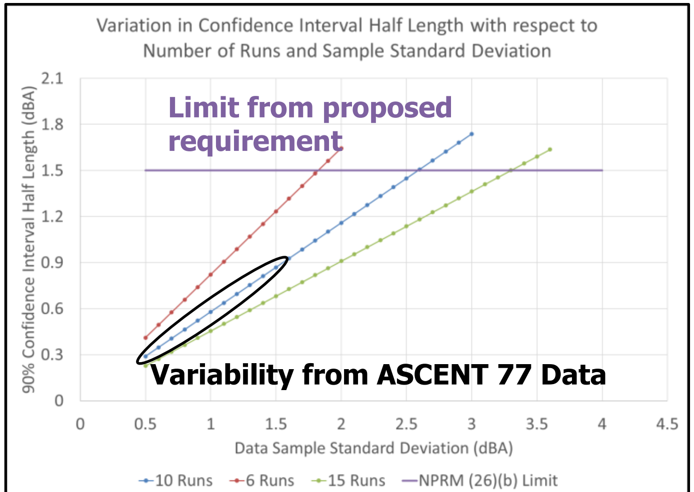
Figure 3.30. Mean and Standard Deviation SEL as a Function of Sideline Distance for Different Flight Velocities.

- Total of 10 runs over two different days
- Range: 0-5 knots.
- Sample Standard deviation: 0.6dBA

Data [1] represents natural variability in UAV operational noise measurements

Does experimental data provide evidence that the proposed requirement is technically feasible?

3 Analyze Drafted Requirements



Analysis of gathered data (by ASCENT 77)

- Map flight test count to observed variability
- Extrapolate variability for varying flight test count

Observations

- Negatively correlated: *More flight tests, less noise measurement variability*
- All observations well within proposed variability requirement: *Not exceeding ±1.5 dB(A)*

Conclusion

- The proposed requirement NPRM 26(b) is *technically feasible*

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[1] Konzel, N. B *Ground based measurements and acoustic characterization of small multirotor aircraft*. Masters Thesis. 2022.

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Summary

Year 2 Progress: ASCENT 61 Team has completed the architecting of a noise certification modeling and assessment framework for transport category aircraft

- Informed by input (training materials and data) provided by VOLPE and OEMs
- Analysis enabled by a probabilistic Process Improvement Model (PIM), which is key for process assessment and evaluation, while experimenting with Equivalent Procedures
- Demonstration through assessing a simplified noise collection/analysis process for Waco YMF-5 propeller aircraft (15% reduction on average costs, 2% reduction on average time required)

- **Next Steps [Transport Category Tasks]:**
  - Add capability for scenario-based experimentation with recommendations for Equivalent Procedures (EP) provided by OEMs
  - Demonstration of EP assessment and prioritization in an interactive decision support environment

Project Scope Pivot for Year 3: Explore applicability of current ASCENT 061 models and analysis tools (currently based on transport category) for certification of rotor or small propeller-driven UAS

- Background and literature search on current noise certification practices for UAS
- Process for repurposing the ASCENT 61 MBSE Noise Certification Framework for UAS Category, to provide oversight on EP and regulatory compliance
- Analysis and assessment on the NPRM 86 FR 48281

- **Next Steps [UAS Category Tasks]:**
  - Update PIM and noise analysis modules
  - Demonstration of noise certification based on NPRM 86 FR 48281
  - Demonstration of EP assessment through certification modeling across different UAS configurations

Publications

- Kim, D., Karagoz, F., Datta, S., Balchanos, M., Anvid, D., Harrison, E., and D.N. Mavris (2022). A Model Based Systems Engineering Approach To Streamlined Noise Certification Of Transport-type Aircraft. In 33rd Congress of International Council of the Aeronautical Sciences ICAS, Stockholm, Sweden, 2022.
- Kim, D., Taneri, M., Omoarebun, E., Balchanos, M., and Mavris, D. (2023). MBSE-Enabled System Verification and Process Improvement of Transport Aircraft Certification. Accepted and to be presented In AIAA SciTech 2023 Forum, National Harbor, MD, January 23-27, 2023.

Thank you for you Audience

Questions? Comments?

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