An Overview of a JMP® Decision Support System for Technology Assessment and Advanced Concepts Analysis for NASA's Environmentally Responsible Aviation Project

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Abstract

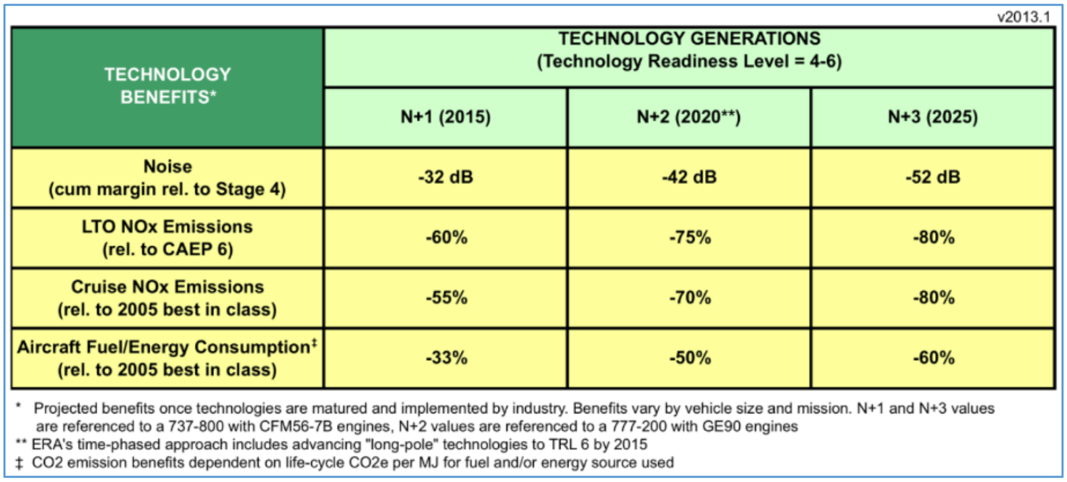
This paper summarizes the capabilities of a JMP-based decision support system (DSS) developed for the NASA Environmentally Responsible Aviation (ERA) research project currently underway at the Aerospace Systems Design Laboratory (ASDL). The ERA project analyzes system-level impacts for subsonic transport aircraft technologies integrated into advanced vehicle concepts that simultaneously meet the project metrics for noise, emissions and fuel burn. Interactive, parametric models become key enablers for e-review sessions to rapidly explore and analyze the design space of potential technologies across the multiple conflicting objectives. Various visualizations and use-cases from the DSS will be explored, including Pareto optimal technology packages, technology uncertainty analysis using probabilistics, MATLAB model integration, and noise contour evaluation at airports.

1 Introduction

The National Aeronautics and Space Administration's (NASA) Environmentally Responsible Aviation (ERA) project funded under the Integrated Systems Research Program was created to conduct research at an integrated system level on promising aircraft concepts and technologies and explore, assess and demonstrate the benefits of chosen concepts and technologies in a relevant environment. ERA's goal is to serve as a technology transition bridge between the lower Technology Readiness Level (TRL)[1] efforts on-going in the Fundamental Aeronautics program and potential users. Specifically, ERA is focused on subsonic transport technologies that could achieve a TRL of 6 by 2020 (N+2) time frame and are capable of being integrated into an advanced vehicle concept that simultaneously meets the project metrics for aircraft noise, engine emissions and aircraft mission fuel burn. The project has established a set of technologies and concepts for which system level analysis is needed to quantify the feasibility, benefits, and risks associated with simultaneously achieving the ERA goals for commercial aviation.

As part of their technology assessment, ERA has contracted the Aerospace Systems Design Lab (ASDL) at the Georgia Institute of Technology to create a technology dashboard or decision support system (DSS). The goal of this DSS is to provide a means of analyzing different combinations of vehicles and technologies and visually displaying the technology impacts in a rapid manner at three different levels of interest: at the subsystem or component level, at the system or vehicle level and at the system of system or fleet level. Each level has its own set of metrics to be evaluated and challenges in efficiently performing the analysis and effectively displaying the data.

The impacts of the individual technologies are defined at the component level. Therefore the DSS must provide the means to quickly evaluate and update the impacts of these technologies. Technologies are grouped into six categories based on their primary impact: airframe weight reducing technologies,



v2013.1

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-52 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

‡ CO2 emission benefits dependent on life-cycle CO2e per MJ for fuel and/or energy source used

Figure 1 NASA ERA Metrics for Noise, LTO NOx and Emissions [2].

airframe drag reducing technologies, airframe noise reducing technologies, engine fuel burn reducing technologies, engine noise reducing technologies and engine emission reducing technologies. The technologies are modeled at the component level so that numerous combinations can be evaluated on a single aircraft. With over 100 different technologies, there are far too many combinations to store every possibility, so the DSS must be able to evaluate the combined technologies' impacts near instantaneously. To further complicate the analysis, certain technologies are incompatible (i.e. they both cannot be placed on the aircraft at the same time) while others must be applied together. Another consideration is the interaction between technologies that lead to different rules for evaluating their performance impact that must be adhered to when combining them on the same vehicle.

At the vehicle level, ERA has established aggressive targets for the reduction of noise, emissions and fuel burn as displayed in Figure 1. ERA has specified a 42 dB reduction in cumulative noise compared to stage 4 noise stringency level [3], as defined by the International Civil Aviation Organization (ICAO), a 75% reduction on Landing and Take-Off (LTO) NOx emissions relative to CAEP 6 emissions stringency level [4], and a 50% reduction in fuel burn relative to a 2005 best-in-class technology level, large twin aisle configuration aircraft (similar to a Boeing 777 aircraft).

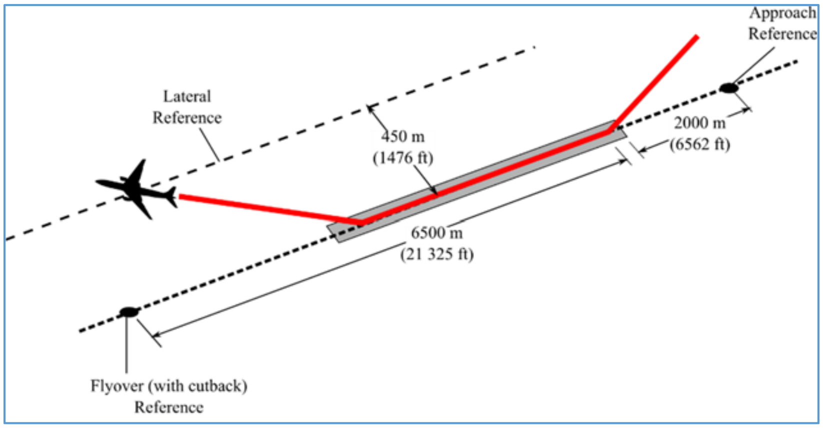


Figure 2 Noise Certification Trajectory

Cumulative noise calculation is the aggregate noise "measured" by microphones at three locations shown in Figure 2 during a "standard" take-off and landing cycle; approach measures the noise of the aircraft as it flies directly overhead during landing, sideline measures the noise of the aircraft from the side of the runway as the aircraft takes off and cutback measures the noise from directly overhead as the aircraft climbs out of the airport. LTO NOx is a calculation of the nitrous-oxide emissions that would be expected to be emitted during a "standard" aircraft landing, taxi and take-off cycle. It is analogous to the testing done to determine a cars fuel economy only measuring NOx emissions. The fuel burn is calculated for a long range "design" mission with a typical payload of passengers and cargo. To maximize the probability of achieving these goals, ERA is evaluating the technology portfolio on several unconventional aircraft concepts in addition to the traditional tube and wing. These unconventional concepts shown in Figure 3 include hybrid wing bodies, various over wing nacelle concepts, and a box wing configuration. Besides the airframe configurations, two different engine concepts were also evaluated; a geared fan and an open rotor.

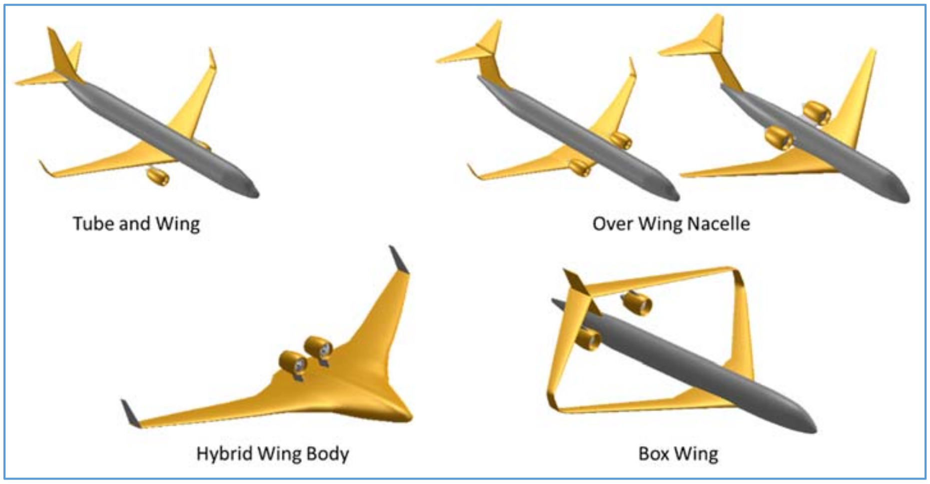


Figure 3 Airframe Configurations

ERA is examining these highly integrated engine/airframe configurations to obtain dramatic improvements in order to achieve these metrics simultaneously. In the past, each metric shown in Figure 1 was evaluated as a corner of the trade space as depicted notionally in Figure 4. A concept optimized for a specific metric along any one axis was expected to achieve the target, but a tradeoff in performance would have to be made in order to improve other metrics of interest. The resulting surface between the metrics represented a technology trade space, depicted as the corner trade space in Figure 4. A corresponding aircraft that equally weighted each of the metrics during optimization would lie at a point on the trade surface in which none of the metrics would be met. The ERA goal of requiring the metrics to be met simultaneously has the effect of expanding the trade surface such that the surface now includes an equally weighted solution representing a more advanced technology trade space. The corner points of this new trade space extend well beyond the original corner points requiring more advanced technologies for an aircraft concept to fall on the expanded trade space.

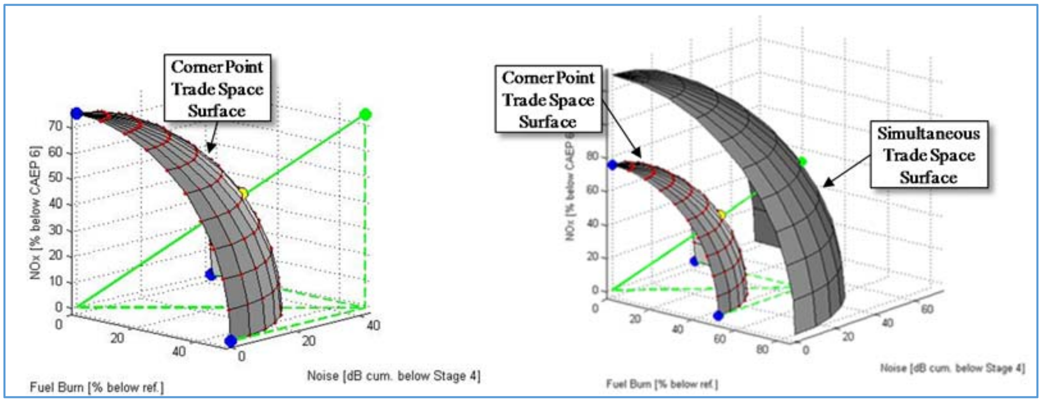


Figure 4 Corner Point vs. Simultaneous Notional Trade Space.

At the fleet level, ERA wants to evaluate fleet performance locally and globally. Locally refers to the area immediately around an airport and focuses only on the aircraft arriving and departing from that airport on a typical day. Globally refers to the impact of every aircraft flying along the entirety of its mission. For simplification purposes, this was reduced to just the flights taking place in the United States plus international flights departing from U.S. airports for a typical day.

The global metrics of interest are total CO2 emissions or total billion gallons of fuel burned and total NOx emissions while the local metrics are airport NOx emissions (emissions below 3000ft) for an entire day at one airport, and airport Day-Night Level (DNL) noise which represents noise exposure over a 24 hour period with noise sources occurring at night receiving a penalty to account for increase human noise sensitivity. The challenge with these metrics is that it takes years for new vehicles to have a noticeable impact on fleet metrics and therefore millions of calculations are necessary to evaluate fleet metrics to a reasonable future date.

In order to expedite the analysis, the aircraft in the fleet were divided into 6 categories of seat classes that define the size of the aircraft and markets served; Regional Jets (RJ), Small Single Aisle (SSA), Large Single Aisle (LSA), Small Twin Aisle (STA), Large Twin Aisle (LTA) and Very Large Aircraft (VLA). All aircraft currently in the global fleet were placed into one of these six categories. A single replacement aircraft was generated for each class as a function of the entry into service date (which set the technology level). Therefore hundreds of different aircraft types would be replaced by only 6 new aircraft types in a particular year.

2 Legacy DSS

The original ERA DSS seen in Figure 5 was developed using Microsoft Excel, mainly due to its availability and ubiquity on most computer systems. While it had several features common with the JMP DSS presented in this paper, it could only handle two vehicle types instead of the eight desired before having memory issues. Additionally, the complex calculation for the fleet metrics could not be performed in any sort of timely manner. Finally, the visualization and interactivity options were limited by comparison.

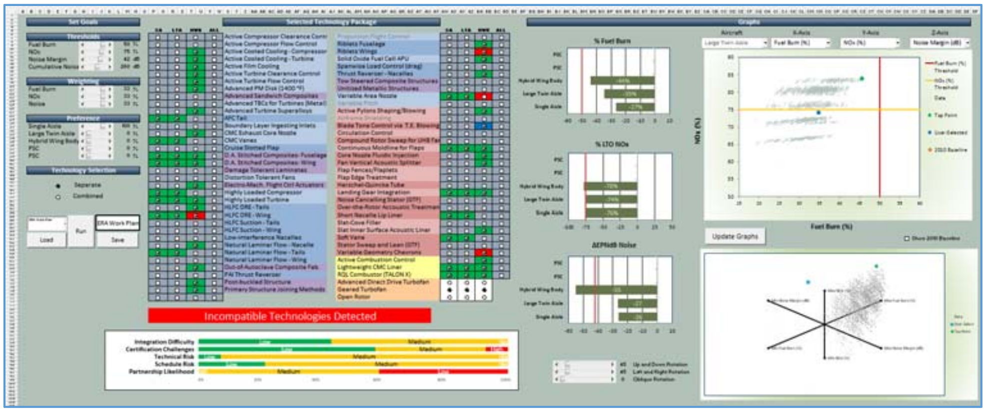


Figure 5 Original Microsoft Excel Version of DSS

The key enabler for the JMP DSS is the use of surrogate models to represent the various analytical codes used to determine the aircraft performance at the aircraft and fleet levels. The use of surrogate models allow for the near instantaneous calculation of the various metrics providing for the evaluation of millions of possible aircraft/engine/technology combinations. The surrogates are neural networks [5] with around 100 input variables. The values for the input variables are specified by a table of technology impacts.

3 ERA DSS Overview

The ERA DSS is broken down into multiple tabs for focused analysis and specific user defined input for the various perspectives of the program. As shown in Figure 6, these tabs include: Technology Combination Analysis, Compatibility, Pareto Frontier Comparison, Probabilistic Analysis, Fleet Definition and Analysis, and Fleet Noise Analysis. The following sections will briefly described the capabilities for each tab and some of the high level trades and types of analyses available for users and decision makers.

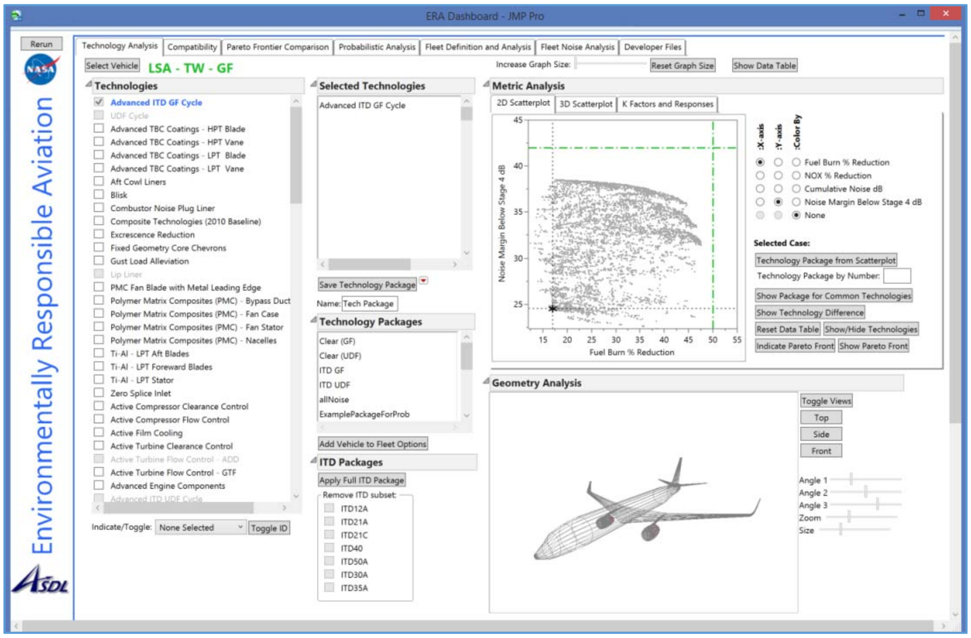
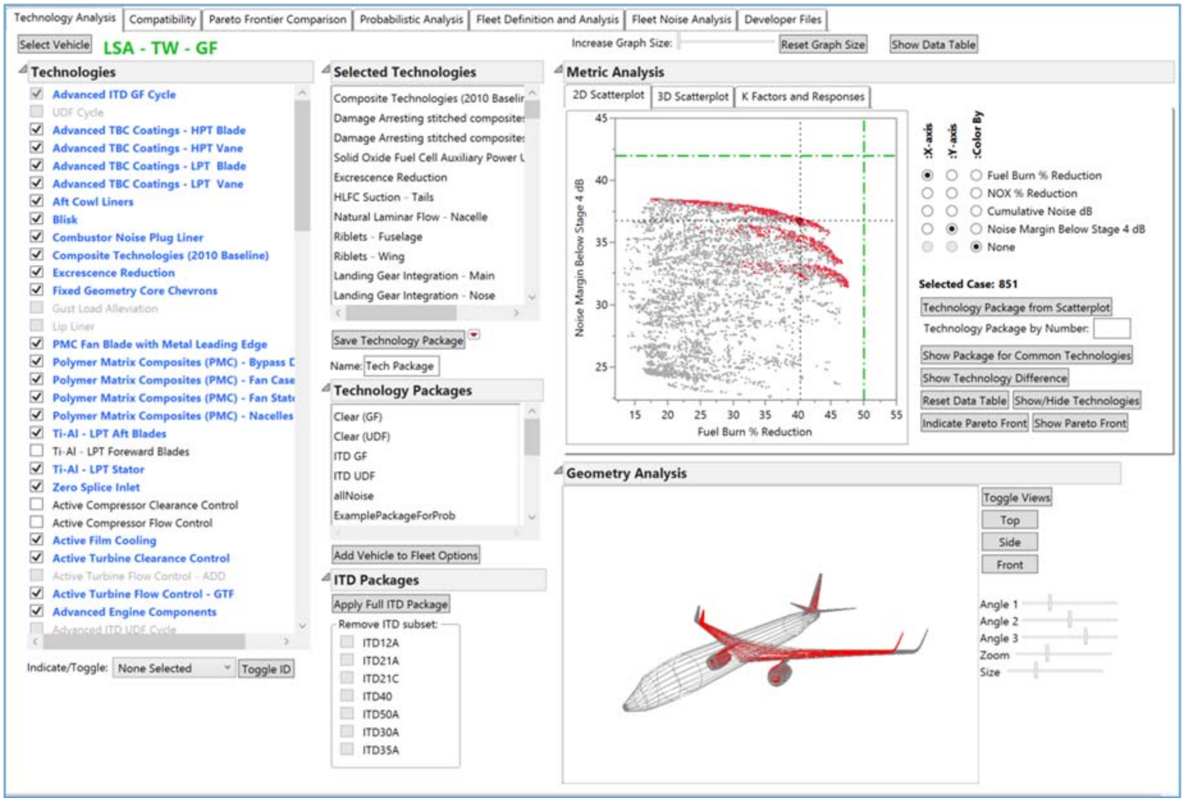


Figure 6 ERA DSS Start-Up Window

4 Technology Analysis

On the first tab of the DSS the user is permitted to define and explore technology combinations or portfolios and evaluate these technologies across the three metrics of interest: NOx emissions, fuel consumption, and noise. The effects of these technologies on additional aircraft metrics are also accessible.

Initially, the user selects one of the eight vehicles each predefined with one of the engine technologies (e.g. geared fan or open rotor). The selection of the aircraft concept will allow or deny certain technologies from being added onto the vehicle via the technology compatibility matrix (described later). Those technologies which are not compatible with the concept's engine technology will be "grayed out" and disabled in the full list of the possible technologies on the far left. The remaining technologies (i.e. enabled and compatible) can be added to the vehicle to improve the performance in one or more of the three metrics of interest.



LSA - TW - GF

☑ Advanced ITD GF Cycle
☐ UDF Cycle
☑ Advanced TBC Coatings - HPT Blade
☑ Advanced TBC Coatings - HPT Vane
☑ Advanced TBC Coatings - LPT Blade
☑ Advanced TBC Coatings - LPT Vane
☑ Aft Cowl Liners
☑ Blisk
☑ Combustor Noise Plug Liner
☑ Composite Technologies (2010 Baseline)
☑ Excrescence Reduction
☑ Fixed Geometry Core Chevrons
☐ Gust Load Alleviation
☐ Lip Liner
☑ PMC Fan Blade with Metal Leading Edge
☑ Polymer Matrix Composites (PMC) - Bypass D
☑ Polymer Matrix Composites (PMC) - Fan Case
☑ Polymer Matrix Composites (PMC) - Fan Stat
☑ Polymer Matrix Composites (PMC) - Nacelles
☑ Ti-Al - LPT Aft Blades
☐ Ti-Al - LPT Foreward Blades
☑ Ti-Al - LPT Stator
☑ Zero Splice Inlet
☐ Active Compressor Clearance Control
☐ Active Compressor Flow Control
☑ Active Film Cooling
☑ Active Turbine Clearance Control
☐ Active Turbine Flow Control - ADD
☑ Active Turbine Flow Control - GTF
☑ Advanced Engine Components
☐ Advanced ITD UDF Cycle

Indicate/Toggle: None Selected

Composite Technologies (2010 Baselir
Damage Arresting stitched composite:
Damage Arresting stitched composite:
Solid Oxide Fuel Cell Auxiliary Power L
Excrescence Reduction
HLFC Suction - Tails
Natural Laminar Flow - Nacelle
Riblets - Fuselage
Riblets - Wing
Landing Gear Integration - Main
Landing Gear Integration - Nose

Name: Tech Package

Clear (GF)
Clear (UDF)
ITD GF
ITD UDF
allNoise
ExamplePackageForProb

Remove ITD subset:
☐ ITD12A
☐ ITD21A
☐ ITD21C
☐ ITD40
☐ ITD50A
☐ ITD30A
☐ ITD35A

:X-axis	:Y-axis	:Color By	
●	○	○	Fuel Burn % Reduction
○	○	○	NOX % Reduction
○	○	○	Cumulative Noise dB
○	●	○	Noise Margin Below Stage 4 dB
○	○	●	None

Selected Case: 851

Technology Package by Number:

Figure 7 Technology Analysis Tab with Selected Technologies

Once the technology is selected (by clicking the corresponding check box) the list of selected technologies in the middle is updated accordingly. This currently selected set of technologies, in connection with the selected vehicle and engine, is then evaluated for their impact on the environmental metrics of interest. This impact is shown graphically in the scatterplot of Figure 7 where the black vertical and horizontal dashed lines indicate the performance of the current vehicle and selected technologies. In this same graph, the green dashed lines indicate the ultimate goal for NASA to reach through technology infusion onto the concept vehicles. For example, by 2020 the NASA goal to decrease fuel burn by as much as 50% is shown in Figure 7.

The cloud of points throughout this graph indicate the relative placement of the performance results of different technologies sets. Thus, the technology combination at concurrently high fuel reduction and at high noise reduction would likely include a large number of technologies with noise suppression and fuel saving techniques. Since this combination would be extremely difficult to find by a user randomly selecting technologies sets on the left, a multi-objective optimization algorithm is applied to the 122 technologies which identifies the dominating set of technology combinations. These combinations, called collectively the Pareto frontier, indicate the technology sets which would offer an improvement in one of the metrics of interest only at the expense or a decrease in the desired direction of another metric when a technology is replaced, added or removed. A genetic algorithm optimizer is used to distribute these technology sets along the Pareto frontier to visually indicate the extent to which the attributes of the technologies can reach the goals set by NASA. The additional gray colored points are also technology combinations but which are dominated by the Pareto-optimal points and, in general, show the entire feasible design space for the selected vehicle. These dominated solutions or combinations indicate that a change to the technology set could improve the metric without a decrement in another.

Since the user may be interested in approaching the goals as closely as possible, the JMP graphing capabilities allows one to select a point on the Pareto frontier, for example, and extract the technologies that comprise that set by clicking on the “Technology Package from Scatterplot” button to the right. This will then populate the selected technologies list appropriately and disable and select the technologies at the far left as well. The user can then make slight additions or deletions to the technology set and make further investigations into the properties of the selected combination.

Furthermore, if a technology set is found to be attractive and promising, it can be saved by clicking on the appropriate button below the list of technologies. Thus, toggling between sets is readily available by selecting from among the saved combinations in turn enabling rapid comparisons of candidate designs (i.e. technology combinations).

The scatterplot graph discussed above permits the user to change the axes such that the other goals or metrics can be quickly visualized and compared. A 3D version (not shown) is also available on the corresponding sub-tab, on which the three metrics can be concurrently plotted and the 3-dimensional Pareto frontier can be seen more easily. In each of these tabs, a matrix of radial boxes is available to define the x, y and z (in the case of the 3D graph) axes and the color of the points plotted.

Although the three environmental metrics are considered the measures for success of the high level NASA goals, additional outputs can be analyzes in table form in the “K-factors and Responses” tab. This tab includes the k-vector for the currently selected technology set if one desires to investigate the assumptions for the technology impacts.

The 3D Geometric Analysis outline box near the bottom right shows the baseline wire frame model of the vehicle in gray and the technology infused vehicle in red overlaid into the same frame of reference. Thus, if the technologies applied result in a reduce take-off gross weight and therefore a smaller required wing area, the wings from the technology infused design will appear smaller as shown in Figure 7.

Lastly, the noise analysis outline box (not shown) contains the impacts of a technology combination in terms of the 65 dB contour overlaid onto a notional runway. This area indicates the extent to which the aircraft will produce noise of 65 dB or greater during a single event (combined take-off and landing). In general, this area is reduced when technologies that suppress noise emitted during both take-off and landing are applied to the technology combination.

5 Technology Compatibility

The Compatibility tab serves as a reference for some of the limitations and actions automatically enabled on the Technology Analysis tab. Since only a subset of all 122 technologies can be listed on an average sized computer screen, turning a technology "on" may disable other technologies that are not visible on the computer screen. After selecting a few technologies, the user may notice that a technology has been disabled that they intended to turn on, but is now found to be incompatible with previous selections. Instead of repetitive scrolling through a trial and error process to identify the incompatible technologies, they can consult the compatibility matrix, shown in Figure 8, to more quickly identify the one or more technologies that are incompatible with a desired one. The compatibility matrix is symmetric and thus only the upper portion is necessary.

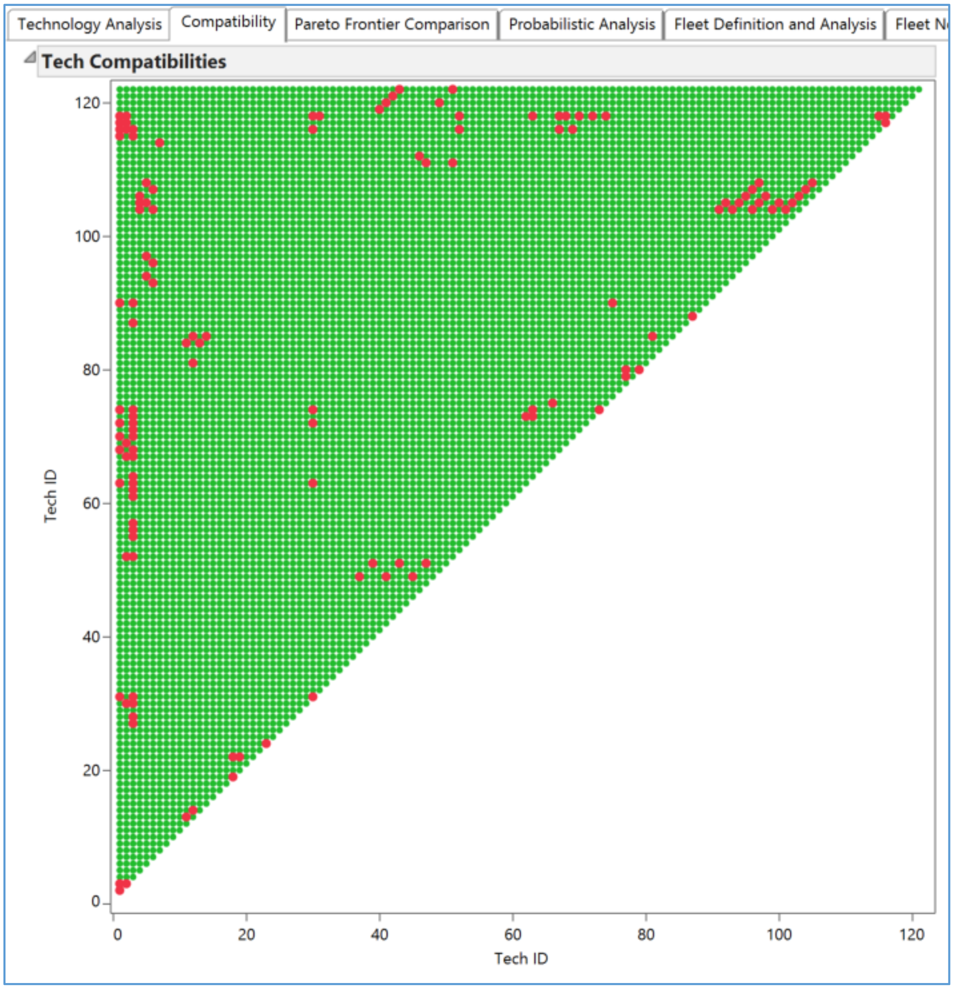


Figure 8 Technology Compatibility Matrix

6 Pareto Frontier Comparison

For each vehicle there exists a Pareto frontier which is comprised of those technology sets or combinations which are dominating all others combinations as described previously. The effect of the vehicle itself also has a significant impact on reaching or exceeding the NASA goals, and thus a comparison between vehicles is necessary to assist in identifying the vehicle concepts, and the accompany technology combinations, which maximize the performance.

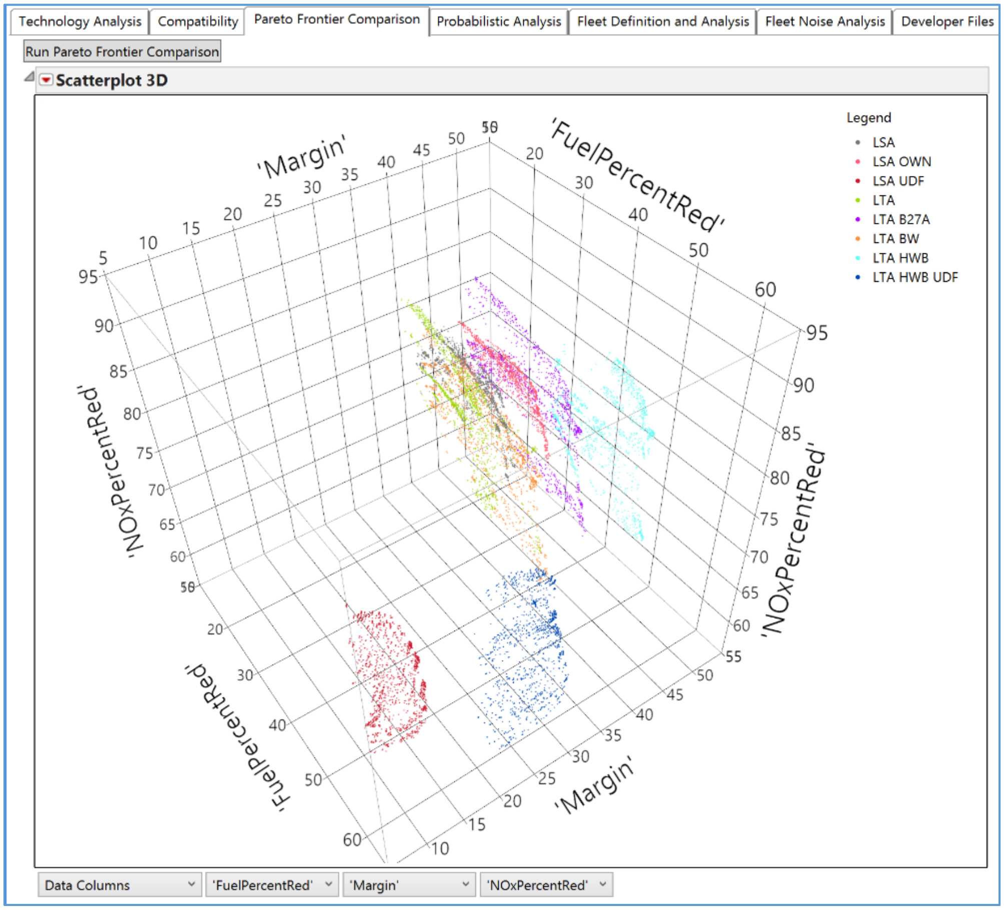


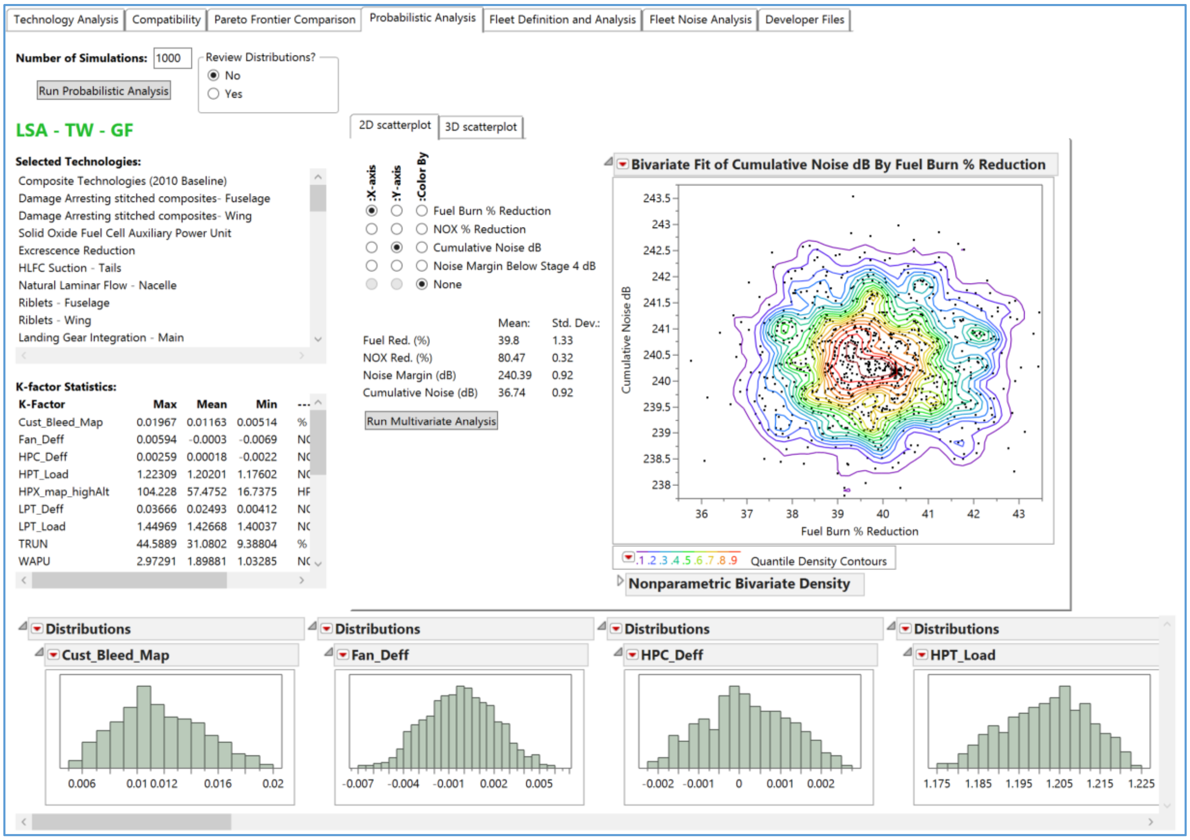
Figure 9 Pareto Frontiers for each Vehicle Concept

By executing the script initiated by clicking on the button, a 3-dimensional scatterplot is created showing the eight vehicle Pareto frontiers across the three environmental metrics of interest. The usefulness of this particular visualization allows the user to identify the areas of the design space at which one vehicle dominates another vehicle for some combinations of technologies. Furthermore, trades between the three metrics from a vehicle perspective are also clearly visible such as when the HWB UDF vehicle, for example, performs much better in terms of fuel consumption, reaching levels of 60% reduction, but does not perform as well in reducing noise when compared to other concepts. This is much more readily seen in the dynamic tool or animated instead of the static scatterplot in Figure 9.

7 Probabilistic Analysis

The Probabilistic Analysis tab performs a similar analysis from the Technology Analysis tab but under the assumption that the impacts on the metrics of interest are uncertain since the specific technology and its precise impacts at the component or subsystem level is unknown. Therefore, a distribution of the impacts for each technology is assumed, on each of the factors of the surrogate model, which in turn will result in a scatterplot of points representing the region that one particular technology combination could achieve.

For example, in Figure 10, the technology combination, which includes approximately 40 technologies, shown in the Selected Technologies list, results in a deterministic design point, shown in the plot on the right with a large black star. However, the specific impacts from those technologies are uncertain. Thus, a distribution for each impact with best, worst and nominal values defined, represents this uncertainty. Since the technologies are all typically at low TRL levels, subject matter experts or other data provide optimistic, pessimistic and realistic perspectives on the impacts of each technology. These values are then used for triangular distributions (used as a default) to represent uncertain impacts. If more than one technology impacts the same component or subsystem, the resultant distribution will appear more similar to a normal distribution as shown on the bottom section of Figure 10. Some statistics of the randomly sample points from these distributions are shown in the middle left. These distributions of impacts are then evaluated probabilistically using the same response surrogate models and are plotted accordingly. The technology package shown in Figure 10, for example, indicates that the true reduction in fuel burn could be as low as 36% but as high as 43%.



Number of Simulations: 1000

Review Distributions?
● No
○ Yes

LSA - TW - GF

Selected Technologies:

Composite Technologies (2010 Baseline)
Damage Arresting stitched composites- Fuselage
Damage Arresting stitched composites- Wing
Solid Oxide Fuel Cell Auxiliary Power Unit
Excrescence Reduction
HLFC Suction - Tails
Natural Laminar Flow - Nacelle
Riblets - Fuselage
Riblets - Wing
Landing Gear Integration - Main

K-factor Statistics:

K-Factor	Max	Mean	Min	---
Cust_Bleed_Map	0.01967	0.01163	0.00514	%
Fan_Deff	0.00594	-0.0003	-0.0069	NC
HPC_Deff	0.00259	0.00018	-0.0022	NC
HPT_Load	1.22309	1.20201	1.17602	NC
HPX_map_highAlt	104.228	57.4752	16.7375	HF
LPT_Deff	0.03666	0.02493	0.00412	NC
LPT_Load	1.44969	1.42668	1.40037	NC
TRUN	44.5889	31.0802	9.38804	%
WAPU	2.97291	1.89881	1.03285	NC

:X-axis	:Y-axis	:Color By	
●	○	○	Fuel Burn % Reduction
○	○	○	NOX % Reduction
○	●	○	Cumulative Noise dB
○	○	○	Noise Margin Below Stage 4 dB
○	○	●	None

	Mean:	Std. Dev.:
Fuel Red. (%)	39.8	1.33
NOX Red. (%)	80.47	0.32
Noise Margin (dB)	240.39	0.92
Cumulative Noise (dB)	36.74	0.92

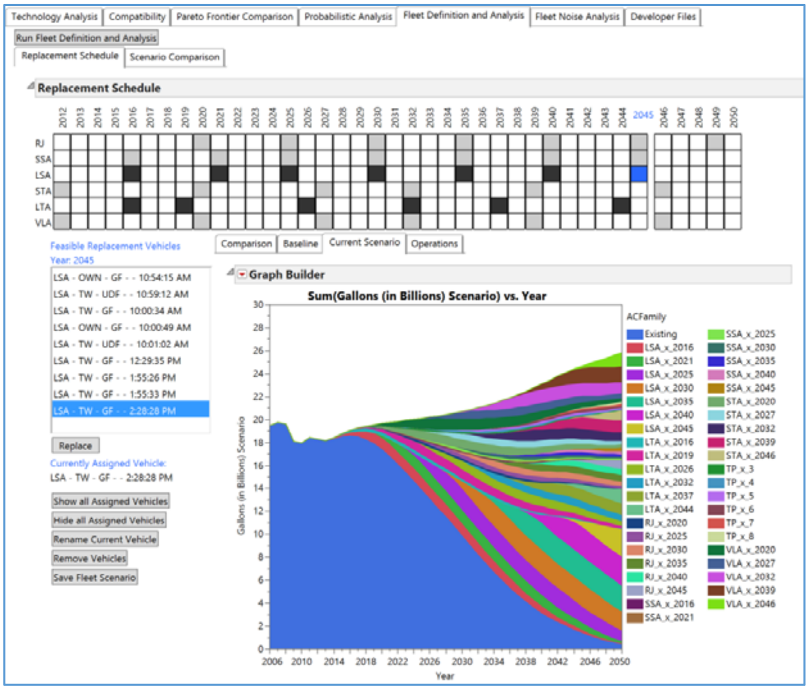
Figure 10 Probabilistic Analysis Tab

As in the case with the deterministic plot, the cloud of points can be visualized in different combinations of output metrics or in a 3-dimensional rendering. The number of points or surrogate model simulations for the scatterplot can be defined in a text box at the top left before the execution of the probabilistic analysis. Although more simulations would “fill in” the cloud of points on the scatterplot, additional computational time is required. When significant simulations are requested, the tool makes use of the JMP to MATLAB connection to harness come of the special capabilities of MATLAB in executing large matrix evaluations when the surrogate models are complex and lengthy [6].

Although not shown, additional assumptions about the distributions can be entered. By selecting “yes” on the option to review distributions before the simulations, a user can select two other types of distributions, namely the uniform distribution, used if no expected value is known and only ranges are forecast, and the beta distribution, where alpha and beta parameters can be adjusted when greater knowledge about the shape of the distribution is available.

8 Fleet Definition and Analysis

All the previous sections have analyzed a vehicle concept and the potential technology combinations with those vehicles in isolation. The Fleet Analysis tab allows the user to take the generated vehicle concepts and technology combinations and apply and investigate those vehicles at the system of system level.



Feasible Replacement Vehicles
Year: 2045

LSA - OWN - GF - - 10:54:15 AM
LSA - TW - UDF - - 10:59:12 AM
LSA - TW - GF - - 10:00:34 AM
LSA - OWN - GF - - 10:00:49 AM
LSA - TW - UDF - - 10:01:02 AM
LSA - TW - GF - - 12:29:35 PM
LSA - TW - GF - - 1:55:26 PM
LSA - TW - GF - - 1:55:33 PM
LSA - TW - GF - - 2:28:28 PM

Currently Assigned Vehicle:
LSA - TW - GF - - 2:28:28 PM

Figure 11 Fleet Definition and Analysis Tab

This tab includes a calendar matrix containing a replacement schedule for six different classes of aircraft (i.e. RJ-regional jet, SSA-small single aisle, LSA-large single aisle, etc.). The shaded boxes represents when a new vehicle can be introduced and will replace retiring aircraft within that class. For example, no new small single aisle concepts can enter the fleet until 2016 as indicated in Figure 11. However, after

2016, all retiring SSA aircraft will assume the characteristics of the replacement vehicle until a different concept replaces this new one at an even later date (e.g. in 2011).

Based on the current list of selected vehicle concepts, only large single aisle and large twin aisle aircraft classes can be replaced with the saved vehicles from previous tabs. Once the user selects a replacement date, a list of saved vehicles will appear and the user can select a vehicle to introduce at that time. For example, in Figure 11, the user has selected 2045 for the LSA class and the ninth "tube and wing" concept in the list of feasible replacement vehicles. The user would then execute the fleet model that takes all the flights performed by that class (i.e. LSA) after 2045 and replace the fuel burn (in this situation) with the reduced fuel burn values. The impact of this replacement choice is then seen on a variety of system-wide fuel burn visualizations. On one of them, shown in Figure 11, the yellow wedge (representing LSA replacement vehicles post 2045) in the area chart shows a reduction after 2045, and, correspondingly, the same chart shows a visible trend change at the top indicating the fuel burn summation for all flights and classes.

In a separate tab, the assumptions about the system level operations can also be compared. In the Scenario Comparison subtab, a list of 13 different scenarios with different forecasting models are assumed. By implementing a filter, the range between the highest and the lowest scenarios in terms of total fuel will be displayed on the figure to the right (as shown in Figure 12). These scenarios show the levels of fuel burn reduction when different groups of technologies are applied across multiple classes. For example, the Business as Usual (BAU) scenario with little or no technology infusions shows the highest level of total fuel required. On the other hand the ITD technology scenarios show the least total fuel or greatest amount of reduction across all scenarios.

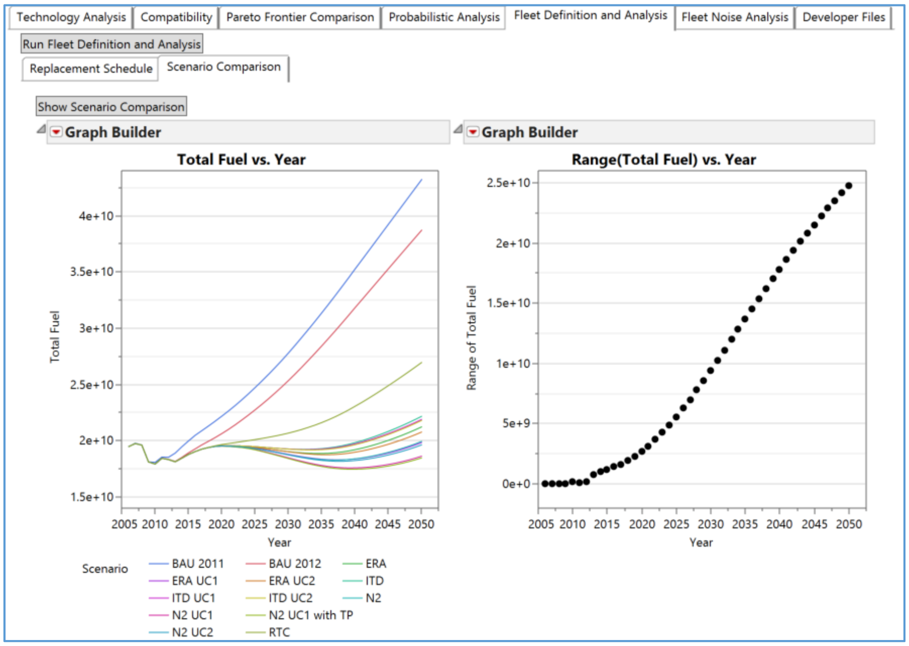


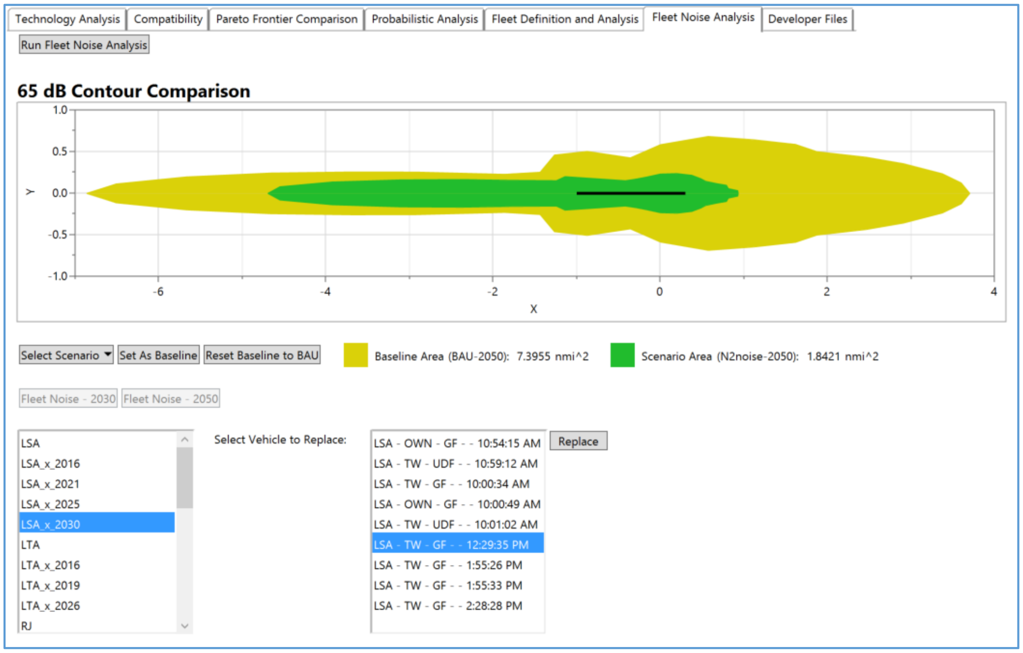
Figure 12 Scenario Comparison Tab

9 Fleet Noise Analysis

The Noise Analysis tab takes the same concept vehicles generated and applied in the fleet analyses but evaluates their impacts for noise contours at a notional airport.

The 65 dB contour is used for comparing before and after replacement vehicles (with noise reducing technologies) are applied. The baseline contour is shown in yellow while the currently defined fleet and replacement vehicles is shown in green. The arrival direction is assumed to occur from the left, while the departing direction is collinear and to the right such as to separate the noise impacts in the key directions and areas of approach, sideline, and cutback. In a similar process, the vehicle class and replacement date is selected and then the specific vehicle which satisfies that schedule can be entered.

If vehicles that performed well in reducing noise at the vehicle level are selected, the area for the scenario contour plot should be significantly smaller, as is shown in Figure 13. As in the case with the total fuel consumed for the fleet, different scenarios can be selected to compare across different technology packages for different years.



🟨 Baseline Area (BAU-2050): 7.3955 nmi^2

🟩 Scenario Area (N2noise-2050): 1.8421 nmi^2

Figure 13 Fleet Noise Analysis Tab

10 Conclusion

The ERA DSS offers considerable capability over previous generations of models used by the NASA ERA program to analyze the impacts of technologies at the vehicle and fleet levels. Many of these capabilities are possible from implementing some of the legacy and new features available in JMP including interactive plotting and visualization, distribution analysis and generation, and the MATLAB to JMP interface. The result is a useful and dynamic decision support system that allows the user to quickly make and investigate trades across the technology design space and analyze the impacts of both technologies and vehicles in the fleet across the environmental objectives of reducing noise, fuel burn and NOx emissions.

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