Project 064 Alternative Design Configurations to Meet Future Demand

Georgia Institute of Technology

Project Lead Investigator

Principal Investigator:
Professor Dimitri N. Mavris
Director, Aerospace Systems Design Laboratory
School of Aerospace Engineering
Georgia Institute of Technology
Phone: (404) 894-1557
Fax: (404) 894-6596
Email: dimitri.mavris@ae.gatech.edu

Co-Principal Investigator:
Dr. Michelle Kirby
Chief, Civil Aviation Division
Aerospace Systems Design Laboratory
School of Aerospace Engineering
Georgia Institute of Technology
Phone: (404) 385-2780
Fax: (404) 894-6596
Email: michelle.kirby@ae.gatech.edu

University Participants

Georgia Institute of Technology

- PIs: Dr. Dimitri N. Mavris, Dr. Michelle Kirby
- FAA Award Number: 13-C-AJFE-GIT-062
- Period of Performance: June 5, 2020 to June 4, 2021
- Tasks:
    1. Support of LTAG-TG Meetings and Technical Ad-hoc Group Meetings
    2. Modeling & Simulation: Development of Turboprop Technology Reference Aircraft
    3. Modeling & Simulation: Assessment of 2050 Projections of Technology Reference Aircraft
    4. Modeling & Simulation: Assessment of 2050 Projections of Advanced Configurations

Project Funding Level

FAA provided $250,000 in funding and the Georgia Institute of Technology (Georgia Tech) has agreed to a total of $250,000 in matching funds which includes salaries for the project director; research engineers; graduate research assistants; and computing, financial and administrative support, including meeting arrangements. The institute has also agreed to provide tuition remission for the students, paid for by state funds.

Investigation Team

Faculty & Research Staff
Dr. Dimitri Mavris, Georgia Institute of Technology, Tasks 1-4
Dr. Michelle Kirby, Georgia Institute of Technology, Tasks 1-4
Mr. Greg Busch, Georgia Institute of Technology, Tasks 1-4
Dr. Jon Gladin, Georgia Institute of Technology, Tasks 2-4
Dr. Gokcin Cinar, Georgia Institute of Technology, Task 2

Graduate Researchers
Melek Ozcan, Georgia Institute of Technology, Tasks 2-4
Luis Salas Nunez. Georgia Institute of Technology, Tasks 2-4

Project Overview

The purpose of this ASCENT project is to support the Committee for Aviation Environmental Projection (CAEP) task group for a Long-Term Aspirational Goal (LTAG-TG), with a focus on aircraft technology modeling and analysis of fuel burn and CO_2 emissions. The LTAG-TG is working under the 12th CAEP cycle to develop scenarios that combine technology, fuels, and operations that represent a range of readiness and attainability for future air transportation. The work will be framed in the context of an analysis of achieving the current International Civil Aviation Organization (ICAO) aspirational goals. The future scenarios will be analyzed to understand the impacts on CO_2 emissions and relating this to current CO_2 levels. The costs associated with the scenarios and the economic impacts on aviation growth, noise, and air quality will be considered and the results will be placed within the context of the latest consensus scientific knowledge. Georgia Tech is supporting the modeling and simulation aspects of these analyses by leveraging the FAA's investment in Georgia Tech's Environmental Design Space (EDS) tool set, existing technology models, and previous work done in support of other CAEP efforts. The goals of Project 064 can be described at a high-level as follows:

- Supporting LTAG-TG and technical ad hoc group (Tahg) meetings.
- Development of a turboprop technology reference aircraft model.
- Execution and assessment of 2050 projections of all technology reference aircraft, all five classes of vehicles (turboprop, business jet, regional jet, narrow body, wide body).
- Execution and assessment of 2050 projection of advanced configuration aircraft; final list of concepts to be considered is still being discussed.

The completion of these tasks will inform the LTAG-TG as to the potential of aircraft technology to reduce fuel burn and CO_2 emissions under a variety of future scenarios.

Task 1 – Support of LTAG-TG Meetings and Technical Ad-hoc Group Meetings

Georgia Institute of Technology

Objective

The objective of Task 1 is to support LTAG-TG meetings and technical ad hoc group (Tahg) meetings within the LTAG Technology sub-group. The CAEP/12 LTAG-TG currently has four primary subgroups: Operations, Fuels, Technology, and Scenarios Development. The key interactions of the overall modeling process for the LTAG-TG are shown in Figure 1.

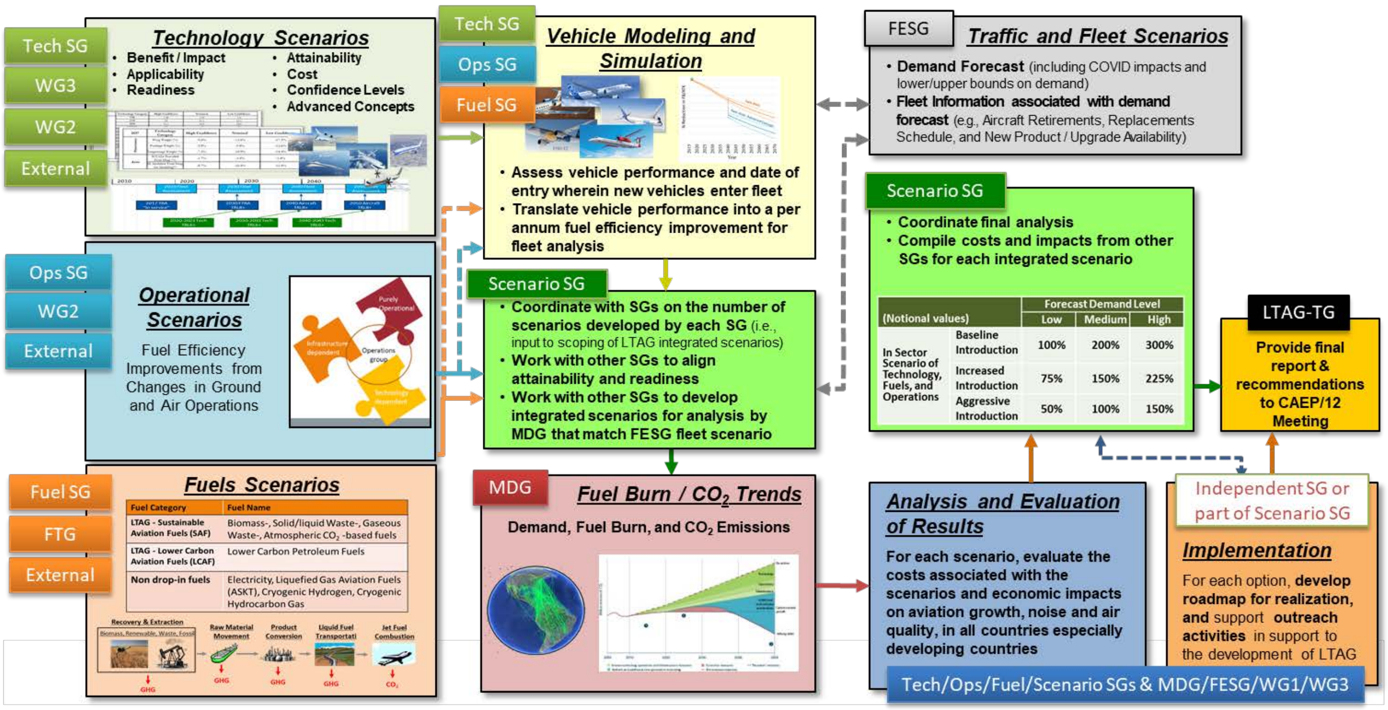


Figure 1. Key interactions for LTAG-TG modeling process.

Georgia Tech is primarily supporting the Technology subgroup, but is actively participating in the other subgroups to help facilitate coordination across the entire LTAG task group. The LTAG Technology subgroup (LTAG Tech SG) is divided into four Tahgs: Airframe, Propulsion, Vehicle Impact Assessment (VIA), and Advanced Concepts and Energy Sources (ACES). The VIA Tahg also contains a sub ad hoc group dedicated to Modeling & Simulation (M&S). Dr. Dimitri Mavris is a co-chair of the Technology subgroup, Dr. Michelle Kirby is a lead focal for the Airframe Tahg, and both Greg Busch and Dr. Dimitri Mavris are focals for the Modeling and Simulation group of the VIA Tahg. A breakdown of the LTAG Technology subgroup is shown in Figure 2.

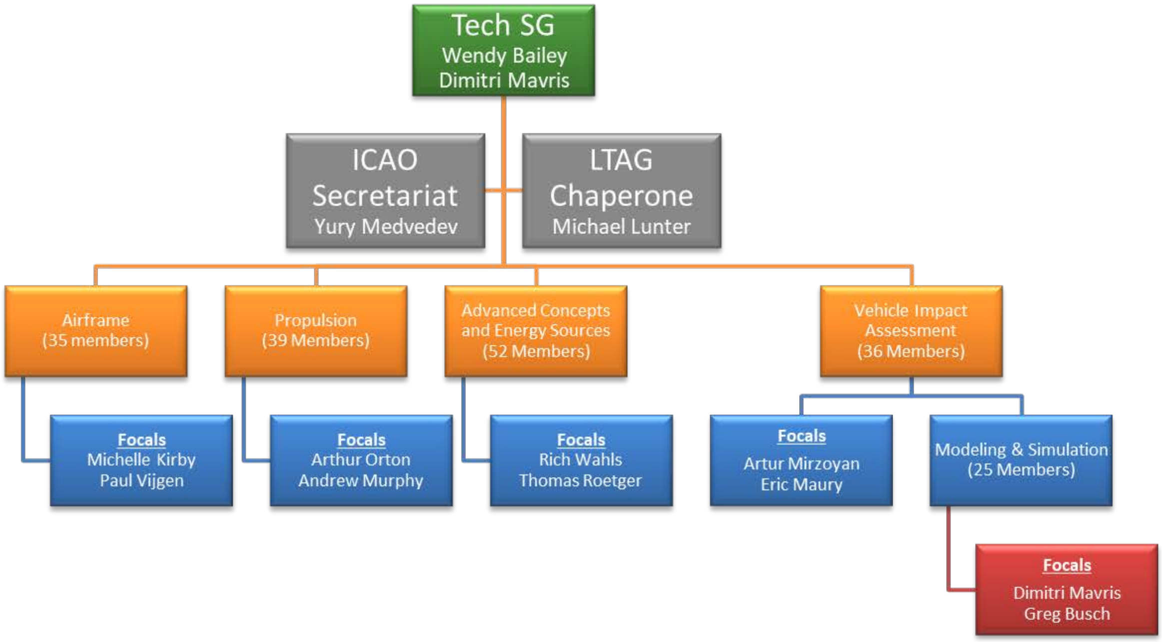


Figure 2. LTAG Technology subgroup structure.

Research Approach

Georgia Tech is supporting the task through hosting and attending various LTAG Tech SG calls, coordinating discussion between its members, and developing workplan proposals for the group. Georgia Tech has also taken on the responsibility for preparing presentations for these meetings, especially for the Tech SG and M&S meetings. There are a large number of LTAG related calls/meetings and many hours have been dedicated to supporting this task. The LTAG Tech SG call schedule continually changes based on the members' availability, but the current schedule of LTAG calls is shown in Table 1. Other activity related to supporting this task are preparing presentations for plenary calls, writing status papers, information papers (IPs) and working papers (WPs), and presenting work summaries at CAEP/12 Steering Group meetings.

Table 1. Current LTAG Technology subgroup call schedule.

Group	Call time
Tech SG	Every other Wednesday, 9-11am
Joint Propulsion + Airframe Tahg	Every other Tuesday, 8-10am
ACES Tahg	Every Monday, 8:00-8:45am
Joint ACES Tahg + VIA Tahg	Every Monday, 8:45-9:15am
VIA Tahg	Every Monday, 9:15-10:00am
Tech SG Chairs + Focals	Every other Wednesday, 8-9am
Modeling & Simulation	Every other Wednesday 9-11am (Tech SG off weeks)

Milestones

- Developed workplan for ASCENT Project 064.

- Supported LTAG-TG at CAEP/12 steering group 2 (SG/2).

Major Accomplishments

- Co-chairing the Tech SG and focals for the Airframe Tahg and M&S ad hoc group.
- Participation in all LTAG related meetings and calls.
- Participating in weekly Tech SG calls and ad hoc group meetings to develop technology impacts across five vehicle classes and preparing material for those calls.
- Refining the methodology, metrics, and process to assess the feasibility of a long-term aspirational goal
- Recurring calls with MDG on fleet level modeling and assumptions.
- Attended stocktaking event.
- Reviewed further submitted questionnaires.
- Wrote status papers for SG/2.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

None

Plans for Next Period

- Continue to support all LTAG-TG meetings and facilitate communication within LTAG.
- Prepare material to be presented and discussed during LTAG meetings.
- Host modeling and simulation meetings to inform members on the modeling objectives and progress.
- Attend and prepare content for LTAG Tech SG workshops 12/7/2020 and 12/14/2020.
- Support and prepare content for CAEP/12 Steering Group meeting 3 in Q2 2021.

Task 2 – Modeling & Simulation: Development of Turboprop Technology Reference Aircraft

Georgia Institute of Technology

Objectives

In order to support the modeling objectives of the LTAG-TG, representative vehicle models are developed and assessed at various timeframes to determine the potential impact of aircraft on the environment in the future. This information will then be used to help inform the LTAG leadership on potential long-term aspirational goals for aviation. The representative vehicle models are based on a current technology reference aircraft (TRA) and then infused with technology impacts in the 2030, 2040, and 2050 timeframes. LTAG-TG is also tasked with investigating advanced concepts for these timeframes and determining their performance characteristics. The current workplan for the LTAG M&S group is to use the TRA vehicles developed under the CAEP Independent Expert Integrated Review (IEIR). This included a TRA model for four different vehicle classes: business jets, regional jets, narrow body aircraft (single aisle), and wide body aircraft (twin aisle). It was requested by LTAG to develop an additional TRA for the turboprop vehicle class, as the electrification of this class of aircraft is likely to occur earlier than other vehicle classes. Georgia Tech is leading the effort to develop this turboprop TRA model to be used in the wider LTAG modeling effort.

Research Approach

The Georgia Tech M&S team is working with industry experts to calibrate the turboprop TRA model. It was decided that the turboprop TRA would represent a notional De Havilland Canada Dash 8-400 aircraft.

Because a majority of the information required to create a TRA model is proprietary to the manufacturers, the TRAs are notional models-characteristics and performance are not required to match identically to the reference aircraft, but need to be close enough to be deemed “fit for purpose” to be used in the LTAG modeling effort. Georgia Tech has developed the turboprop TRA using EDS and currently in the process of getting it approved as fit for purpose. The TRA models are created using the modeling & simulation tool suite EDS by Georgia Tech/FAA/NASA and will go through the following process:

1. Collection of publicly available data on reference aircraft.
2. Review of data assembled with M&S ad hoc team and industry experts.
3. Develop EDS model comprising of a Flight Optimization System (FLOPS) vehicle model, Numerical Propulsion System Simulation (NPSS) engine model, and Aircraft Noise Prediction Program (ANOPP) noise model.
4. Calibrate EDS model to match performance characteristics.
5. Review calibrated weights, engine cycle, and performance with M&S ad hoc team.
6. If results are “fit for purpose” then modeling of TRA is complete. If not, then change modeling assumptions/inputs and return to step #4.

Georgia Tech has gone through multiple iterations of the turboprop TRA and has gotten valuable feedback from industry experts from De Haviland Canada, Pratt & Whitney Canada, and Dowty propellers. The current TRA model is very close to “fit for purpose," and only requires some minor updates based on feedback from Dowty. The current performance metrics for the turboprop TRA are shown in Figure 3 and Figure 4. The current CO_2 metric value for the turboprop TRA stands at 0.517 kg/km. Georgia Tech is currently working on finalizing the TRA model and expects to accomplish this by the end of 2020.

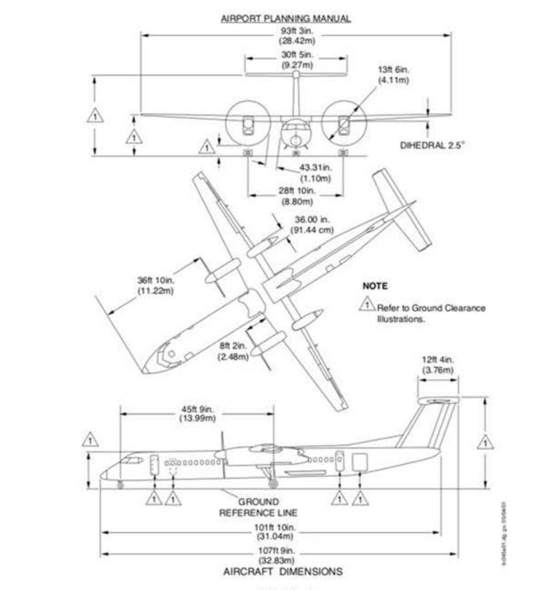
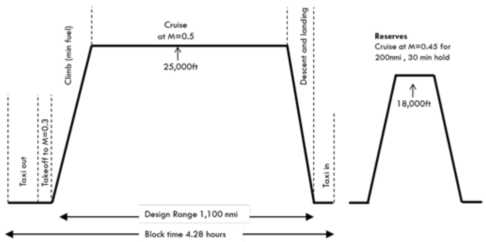


Image Ref: Bombardier, Q400 Airport Planning Manual
Values obtained or measured from this reference.

Description	Value
Design Range	1,100 nmi
Design Payload	16,650 lbs / 7,552 kg
Design Cruise Mach No.	0.5 (Long Range Cruise)
Trip Fuel	7,459 lbs / 3,383 kg
Take-off Field Length	4,671 ft / 1,424 m
Approach Speed	117 kts / 60.2 mps
Max L/D (cruise)	16.2
CLmax Take-off	2.5
CLmax Landing	2.8
R1 Range	750 nmi
R1 Max Payload	18,696 lbs / 8,481 kg

Figure 3. Turboprop TRA current top-level metrics.



FUEL BURN

Trip Fuel 7,459 lbs
(3,383 kg)

	M&S Group
TP Technology Reference Aircraft Trip Fuel	3,383 kg
TP Technology Reference Aircraft MTOM	29,574 kg
TP TRA CO2 Metric ((1/SAR)$_{AVG}$/(RGF^0.24))	0.517 kg/km
TP Fuel Burn per Available-Ton-Kilometer	0.179 kg/ATK

Figure 4. Turboprop (TP) TRA current fuel burn performance.

Milestone

Created a representative EDS model for the turboprop technology reference aircraft and iterated with industry experts to achieve “fit for purpose” status on fuel burn performance.

Major Accomplishments

- Gathered publicly available information on the De Haviland Canada Dash 8-400.
- Developed FLOPS vehicle model for turboprop TRA.
- Developed NPSS engine model for PW150A turboprop engine.
- Iterated with industry experts and are approaching finalized “fit for purpose” values.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

Melek Ozcan, Graduate Research Assistant: Supporting modeling and simulation using EDS.
Luis Salas Nunez, Graduate Research Assistant: Supporting modeling and simulation using EDS.

Plans for Next Period

- Finalize turboprop TRA model by incorporating feed on propeller performance from Dowty.
- Model LTO noise of the turboprop TRA.
- Get approval from modeling and simulation ad hoc group to deem the turboprop TRA "fit for purpose."

Task 3 – Modeling & Simulation: Assessment of 2050 Projections of Technology Reference Aircraft

Georgia Institute of Technology

Objectives

The objective of Task 3 is to perform assessments of future tube and wing (conventional) aircraft variants of the technology reference aircraft models. This task includes taking technology impacts for three different timeframes (2030, 2040, and 2050) and applying them to the five technology reference aircraft classes:

- Turboprop
- Business Jet
- Regional Jet
- Narrow body
- Wide Body

The technology impacts will be provided by the Propulsion and Airframe Tahgs within the LTAG technology subgroup and implemented onto the TRA models by the M&S group (led by Georgia Tech) of the VIA technical ad hoc groups. This task will initially be performed for the wide body vehicle class as the proposed "sample problem" to execute the entire LTAG modeling process. The objective of the sample problem is to go through the modeling methodology from front to back and include all the interactions and exchange of information between the various LTAG subgroups in an effort to establish a well-working methodology. This methodology will then be applied to the remaining four vehicle classes.

Research Approach

The LTAG technology subgroup vehicle impact assessment process, shown in Figure 5, will be followed to accomplish the objectives of Task 3. This process includes all of the LTAG Tech SG technical ad hoc groups, with Georgia Tech primarily operating under the VIA Tahg. The Propulsion and Airframe Tahgs are currently in the process of down selecting technologies and determining the impacts to be provided to the VIA Tahg. These technology impacts will be provided at three different confidence levels: 80% confidence (high), 50% confidence (nominal), and 20% confidence (low). Once the technology impacts have been determined, they will be provided to Georgia Tech (as part of the VIA Tahg) and will be translated into modeling factors to be input in EDS for the modeling assessment. EDS will be used to model the future technology projection of all five vehicle classes at each timeframe and confidence level. For example, the wide body vehicle class assessments will result in fuel burn performance for nine different technology vehicles as follows:

- 2030 timeframe
  - High confidence technology wide body
  - Nominal confidence technology wide body
  - Low confidence technology wide body
- 2040 timeframe
  - High confidence technology wide body
  - Nominal confidence technology wide body
  - Low confidence technology wide body
- 2050 timeframe
  - High confidence technology wide body
  - Nominal confidence technology wide body
  - Low confidence technology wide body

The predicted noise levels for these aircraft models will also be assessed and tracked to ensure the technology packages on the future variants do not result in a significant increase in LTO noise. These assessments will be repeated for the other vehicle classes resulting in a total of 50 vehicle models being developed by Georgia Tech for Task 3: 45 technology aircraft (5 classes X 9 technology variants) and five 2017 technology reference aircraft. Once the performance metrics of the aircraft are determined, the fuel burn per available-ton-kilometer (ATK) relative to the 2017 TRA vehicles will be provided to the CAEP MDG group for fleet assessment. A notional table is shown in Table 2. MDG will use the fuel burn metrics to assess the impact of the technology vehicles on the fleet fuel burn projected out to the year 2070. The fleet results will be returned to the LTAG TG and the outcomes, along with economic impacts, will be utilized by LTAG to conduct a final analysis. LTAG will provide CO_2 emissions impacts, economic impacts, and technology roadmaps for each of the integrated scenarios to be brought forward to CAEP leadership.

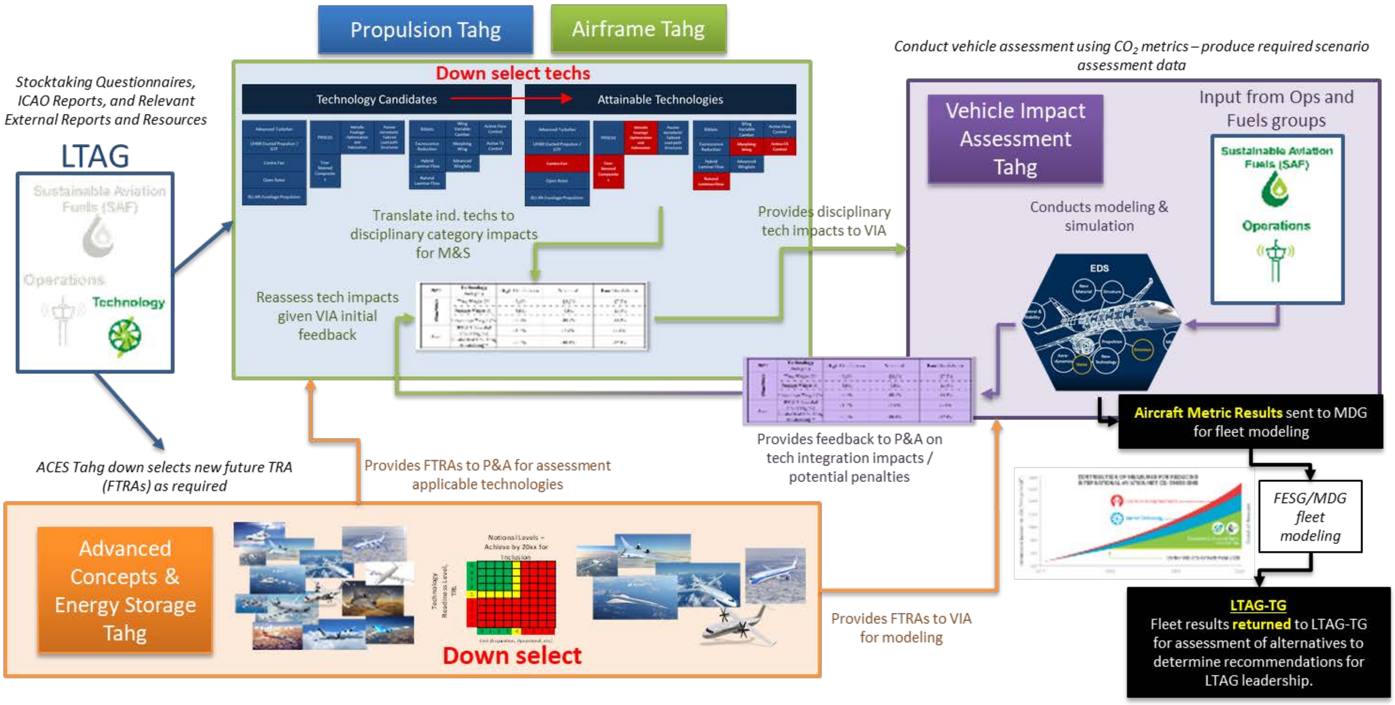


Figure 5. LTAG Tech SG assessment process.

Table 2. Notional table of fuel burn results to be provided to MDG.

Fuel Burn Per Annum Improvement rel. 2017 TRA (% Fuel Burn / ATK)					
		Timeframe			
Vehicle Class	Confidence Level	2017-2030	2030-2040	2040-2050	2050+
Turboprop	Low	0.67%	1.25%	0.96%	1.17%
	Nominal	0.72%	1.30%	1.01%	1.22%
	High	1.42%	2.00%	1.71%	1.92%
Business Jet	Low	0.37%	0.95%	0.66%	0.87%
	Nominal	0.42%	1.00%	0.71%	0.92%
	High	1.12%	1.70%	1.41%	1.62%
Regional Jet	Low	0.72%	1.24%	0.98%	0.95%
	Nominal	0.77%	1.29%	1.03%	1.00%
	High	1.47%	1.99%	1.73%	1.70%
Single Aisle	Low	1.21%	1.13%	1.17%	1.28%
	Nominal	1.26%	1.18%	1.22%	1.33%
	High	1.96%	1.88%	1.92%	2.03%
Twin Aisle	Low	0.99%	1.47%	1.23%	1.25%
	Nominal	1.04%	1.52%	1.28%	1.30%
	High	1.74%	2.22%	1.98%	2.00%
Adv. Concept A	Low	N/A	2.07%	2.05%	2.45%
	Nominal	N/A	2.12%	2.10%	2.50%
	High	N/A	2.82%	2.80%	3.20%
Adv. Concept B	Low	N/A	N/A	3.17%	4.15%
	Nominal	N/A	N/A	3.22%	4.20%
	High	N/A	N/A	3.92%	4.90%

Notional

Milestones

- Established vehicle impact assessment methodology for LTAG Tech SG.
- Established timeline for LTAG modeling and simulation deliverables.
- Proposed wide body sample problem to use as a test case for modeling methodology.

Major Accomplishments

- Verified performance of 2017 TRA models for business jet, regional jet, narrow body, and wide body classes (working on turboprop vehicle class as described in Task 2)
- Established required technology impact input to be delivered from Propulsion and Airframe Tahgs.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

Melek Ozcan, Graduate Research Assistant: Supporting modeling and simulation using EDS.
Luis Salas Nunez, Graduate Research Assistant: Supporting modeling and simulation using EDS.

Plans for Next Period

- Receive technology impacts for all five vehicle classes and translate impacts to modeling factors for use within EDS.
- Participate in LTAG Tech SG workshops to answer final outstanding questions regarding LTAG modeling process and establish required exchanges of information between the LTAG technology, fuels, and operations subgroups.
- Execute the modeling and simulation for the wide body sample problem.
- Complete modeling assessment for all vehicle classes/timeframes/confidence levels.
- Provide results to LTAG Tech SG and CAEP MDG for fleet assessment.
- Documentation of modeling and simulation process and methodology.

Task 4 – Modeling & Simulation: Assessment of 2050 Projections of Advanced Configurations

Georgia Institute of Technology

Objectives

The objective of Task 4 is to perform assessments of future advanced (unconventional) aircraft variants of the technology reference aircraft models. Task 4 is similar to Task 3 but applied to advanced aircraft configurations. These advanced configurations can include advanced airframe architectures, propulsion architectures and unconventional fuel systems. This task also includes taking technology impacts for three different timeframes (2030, 2040, and 2050) and applying them to the five technology reference aircraft classes:

- Turboprop
- Business Jet
- Regional Jet
- Narrow body
- Wide Body

The particular advanced configurations selected for use in the LTAG study will be done by the ACES Tahq, and has currently not been finalized. Georgia Tech is working with the focals of the ACES Tahg to help determine the advanced concepts to be used and provide potential options for modeling the impacts of these aircraft in the future timeframes of interest.

Research Approach

The research approach for this task is still being finalized but will most likely follow the same process described in Task 3 and shown in Figure 5. The results of the task are similar to those in Task 3; the fuel burn performance metrics for the advanced concept aircraft are to be assessed for the 2030, 2040, and 2050 timeframes and provided to MDG for including in the fleet analysis. The approach for determining the performance of the advanced concepts is still under consideration. Georgia Tech has proposed that some of the advanced concept vehicles could be modeled and assessed through EDS, in a comparable way to the conventional tube and wing aircraft. Georgia Tech has also proposed that for the advanced concept variants that do not currently have a representative EDS model, the fuel burn performance could be determined through referencing studies and publications available in the public domain. Given the short time remaining to complete the entirety of the LTAG analysis, this could prove to be a prudent option for some or all of the advanced concepts that will be proposed by the ACES Tahg. It has been determined that the blended wing body (BWB) will be used as the advanced concept for the wide body sample problem. Georgia Tech is in the process of gathering information on the available models available for modeling and/or assessment.

Milestone

- Helped guide the selection of an advanced concept for the wide body sample problem, a blended wing body variant.

Major Accomplishments

- Helped establish a down selection process of the advanced concepts for the ACES Tahg.
- Provided information on available advanced concept models currently in Georgia Tech's EDS suite of aircraft models.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

Melek Ozcan, Graduate Research Assistant: Supporting modeling and simulation using EDS.
Luis Salas Nunez, Graduate Research Assistant: Supporting modeling and simulation using EDS.

Plans for Next Period

- Assist ACES Tahg in the down selection process for advanced concepts for all vehicle classes.
- Finalize the methodology to be used for assessing the fuel burn / emissions impact of advanced concepts.
- Perform the vehicle impact assessment for the blended wing body as part of the wide body sample problem.
- Perform the vehicle impact assessment for all other advanced concepts in all five vehicle classes, either through using EDS models or information from publicly available studies.