



Project 106(A) Integration of Turbine Operational Parameters into Aerothermal System Analyses

Georgia Institute of Technology

Project Lead Investigator

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- P.I.: Dr. Dimitri N. Mavis
- FAA Award Number: 13-C-AJFE-GIT-173
- Period of Performance: January 21, 2025, through January 20, 2026
- Tasks:
 1. Develop Baseline Models and Turbine Modeling Framework
 2. Integrate Experimental Data
 3. Demonstrate Impact of New Models

Project Funding Level

The Federal Aviation Administration (FAA) provided funding of \$200,000. Georgia Tech agreed to a total of \$200,000 in matching funds. This total includes salaries for the project director, research engineers, and graduate research assistants, as well as computing, financial, and administrative support, including meeting arrangements. Georgia Tech has also agreed to provide tuition remission for the students, paid for by state funds. During the period of performance, in-kind cost sharing is also obtained for cost share.

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Georgia Institute of Technology

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Graduate Students:

Anand Iyer—Task 1, turbine loss model development
Niharika Akula—Task 1, turbine disk structural modeling and optimization
Esteban Pais—Task 1, turbine cooling model development
Sindhu Belki—Task 1, turbine size effects modeling and analysis
Jessica Tang—Task 1, turbine modeling framework development

Undergraduate Students (not funded):

Charles Howard—Task 1, turbine cooling model development
Ethan Cordeiro—Task 1, turbine loss model literature review





Project Overview

Gas turbine engines will continue to be the propulsion power plant of choice for large single- and twin-aisle aircraft in the foreseeable future because of their high power and energy density capabilities. However, these engines produce 90% of today's carbon dioxide emissions in the aviation sector. While turbine engines are ubiquitous in propulsion, many advances made stem from improvements in individual component efficiencies rather than system-level approaches which can quantify the inter-relations of engine operations. These operational impacts are particularly important as new architectures are explored and designed. One key component where there is a lack of information to improve operational models and thus difficult to predict thermal efficiency trends, is the turbine; here the complexities of cooling and leakages make this task exceptionally challenging. The goal of this task was to acquire data from the test turbine in The Pennsylvania State University (Penn State) Steady Thermal Aero Research Turbine (START) Lab (researchers under ASCENT Project 106B), under carefully controlled conditions to build a library of specific operational impacts on thermal efficiencies and then integrate this library of data into the modeling tools of Georgia Tech's Aerospace Systems Design Laboratory (ASDL). This effort intended to result in accurate operational trade-offs with cooled turbines whereby the modeling tools can be widely used by industry to assess sustainability concepts.

Key to being able to identify new turbine architectures is to understand thermal efficiency losses that result from blade cooling, tip clearances, purge flows, manufacturing variability, and stage gaps. Missing, however, are data on each specific loss mechanisms under carefully controlled and well-documented turbine operations. The primary reason for this lack of data is the rarity of test facilities capable of independently assessing turbine operational parameters and even fewer facilities that are able to make highly accurate thermodynamic efficiency measurements. Penn State's START Lab not only has developed a measurement capability which provides highly accurate stage efficiency measurements but also has the ability to independently vary turbine airfoil cooling flowrates; locations of where this coolant is injected back into the main hot gas path, i.e., trailing edge, blade tip, etc.; blade tip gaps; inlet temperature and turbulence profiles; under-platform sealing flowrates needed to minimize hot gas ingestion; airfoil manufacturing methods; and gap sizes between the vane and blade. All of these operational features significantly impact thermal efficiencies, as has been previously shown through preliminary measurements taken in the START Lab. Through National Aeronautics and Space Administration (NASA) University Leadership Initiative (ULI) collaborations, the START Lab and ASDL have identified a gap in data available that benchmarks thermodynamic efficiency losses of specific features. This project intended to leverage the use of several available test turbines including the START Lab's National Experimental Turbine (NExT) to do detailed efficiency measurements by controlling specific turbine operational features.

Georgia Tech's ASDL worked with the Penn State START Lab to collaborate on creating an aero-thermodynamic model of a high-pressure turbine capable of integrating the operational parameters library from the START lab. This endeavor aims to develop detailed design algorithms, systems of equations, and Numerical Propulsion System Simulation (NPSS) code to calculate the necessary turbine operational parameters for a given cycle while interfacing with the experimentally determined library. The approach was intended to be refined using an example engine model based on a state-of-the-art engine for calibration purposes. Additionally, several other "future" cycle models were intended to be developed to assess the significance of incorporating these impacts in future sustainable aircraft studies. These future cycles to be considered were sought to be selected to align with past and future FAA studies, such as the International Civil Aviation Organization (ICAO) Long Term Aspirational Goal (LTAG) analysis and other pertinent research. Following the development of the approach and integration of the operational parameter library from the START lab, a "before and after" benchmark study was planned to be conducted to demonstrate the impact of the work across the spectrum of included cycle models.

Georgia Tech has experience in creating detailed cycle models of gas turbine engines for aviation applications. These models are typically calibrated to public domain data and used to perform technology assessments to support government investment decisions, international (ICAO) goal setting and stringency exploration exercises and other relevant studies. Examples of this kind include the FAA Continuous Lower Energy, Emissions and Noise system assessment (ASCENT Project 037), and the long-term aspirational goals study with ICAO (ASCENT Project 064). Georgia Tech's models have been central in conducting these studies, in particular the use of the environmental design space (EDS). This tool has been used to create a database of notional engine models of current best in class vehicles for both short, medium, and long-haul applications. The model results have been approved by various members of industry who participated in these studies and deemed the results to be fit for the purpose of conducting high-level technology exercises. EDS is also used to support many studies for other aviation partners such as NASA, Air Force Research Laboratory, and various industrial partners.



While these achievements are significant, the development of the EDS engine model database relies upon constant development of the physics-based models operating in the background. Key features of these models play important roles during the design process and selection phases that ultimately impact the technology selection. A more recent part of the process engages the parametric design space and optimization capabilities that have been developed using the EDS tool. This means that future study results will be even more sensitive to having accurate parametric representations of detailed components within the baseline model, thus motivating the improvement of various component models.

Under prior work with the NASA ULI program, topics of small core scaling effects have been evaluated, and the results are illustrated qualitatively in Figure 1. In Figure 1, an ideal scaling curve represents the effect on high pressure turbine (HPT) efficiency, assuming a geometric scaling approach. However, many of the scaling effects are non-ideal, which is represented by the steep drop of efficiency when small core effects are taken into consideration. From a high-level perspective, some of the driving influences of these efficiency debits have been identified and are also summarized with qualitative influence in Figure 1. One of the most important effects (#1, tip gap effects) is under separate analysis in the prior ULI program. However, other significant driving parameters were modeled and sought to be evaluated as part of this effort specifically for purposes of building modeling approaches to benefit future engine designs. Accurately modeling these effects is very important in defining and deciding on future engine cycles and determining appropriate goals for carbon dioxide emission reductions.

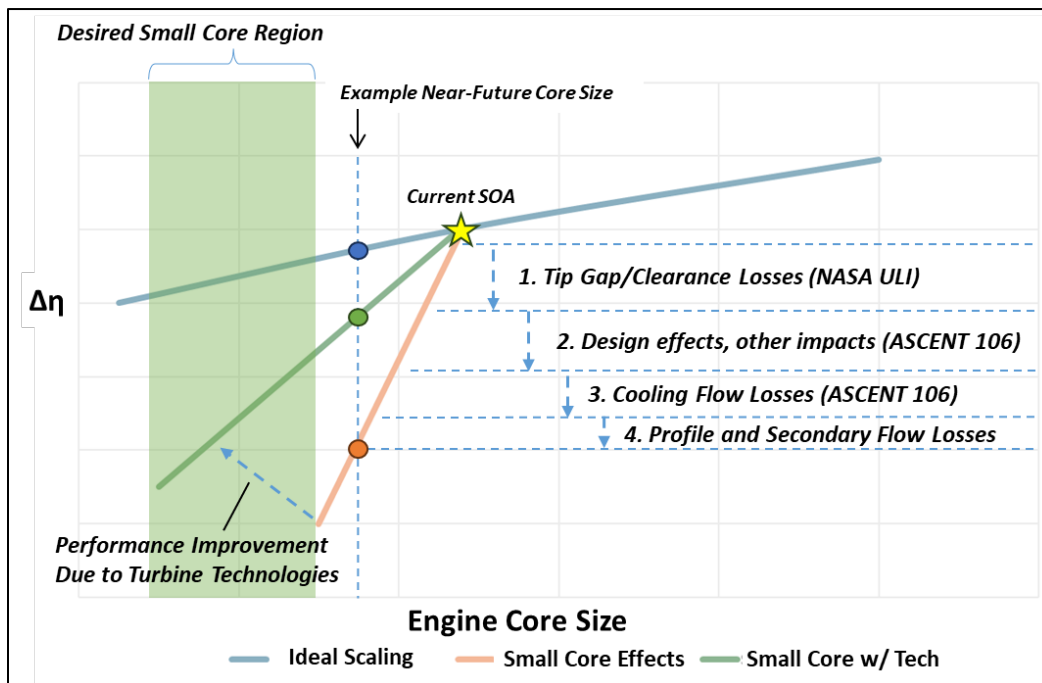


Figure 1. Small core scaling effects on high pressure turbine (HPT) efficiency. NASA: National Aeronautics and Space Administration, SOA: State of the Art, ULI: University Leadership Initiative.

The overall project scope and plan consist of three years of proposed effort. The work has been completed in partnership with the Penn State University START lab, who has performed partner tasks to perform experimental investigations of parametric turbine performance. The work pursued in the Year 1 effort focused on building a modeling framework for a baseline geometry and coordinating data analysis and integration with the team at Penn State START through their experimental measurements.

In Year 1, the project team worked to create a calibrated stage loss model of the turbine based on experiments from the NEXt turbine at the Penn State START lab. A baseline turbine model was developed for the first stage of a HPT. This design was intended to map the overall flow-path geometry (i.e., scaled hub/tip radii, etc.) and scaled flow rates. A literature review was conducted to define a turbine stage loss model that is parametric to the design parameters of the turbine



stage. This loss model includes geometry and aero-thermal design impacts, small feature impacts, and cooling flow impacts. The theoretical aspects of the model were documented in detail across the development effort. The development of the model was out using the open-source turbine analysis code, Turboflow, as its basis, and the modified model can be shared with other partners who carry out extensions of the turbine analysis.

In Year 1, measurements conducted at Penn State were documented by the START team, with the intent to share these data packages with the Georgia Tech ASDL to complete Task 2, which included calibrating the baseline model developed in Task 1. Looking ahead, in Year 2, comparisons of the baseline turbine model with the measured efficiencies from the Year 1 experiments were planned to be completed. A detailed effort to calibrate these models was planned, with an effort made to parse out specific components of the loss models that contribute to the error. It was then intended to include an analysis of the impact of cooling flows on efficiency, as well. The model was planned to be integrated into a state-of-the-art calibrated engine model to determine differences between current model calibration. In Year 3, Georgia Tech then expected to integrate models for small core features to be tested in Year 2 and geometric sensitivities to be conducted in Year 3. The model was intended to be integrated into several different cycle models that have been used for FAA studies in the past to demonstrate differences in the cycle model parametric optimization. The final version of the turbine component modeling framework was planned to be delivered and documented in Year 3. A full technical schedule which was planned for ASCENT Project 106A is provided in Table 1, and a list of the ASCENT Project 106A Plan of Actions and Milestones is shown in Table 2.

Table 1. Overall plan for the ASCENT Project 106A program.

Project Year		Year 1				Year 2				Year 3			
Calendar Year Quarter		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Calendar Year		2025				2026				2027			
Task 1: Develop Baseline Models													
	1.1: Literature review												
	1.2: Coordinate model and turbine experiments												
	1.3: Develop baseline turbine model												
Task 2: Integrate experimental data													
	2.1: Integrate baseline data												
	2.2: Integrate cooling sensitivities												
	2.3: Integrate small core impacts												
	2.4: Integrate alternate geometry experiments												
Task 3: Demonstrate impact of new model													
	3.1: Integration into selected cycle models												
	3.2: Evaluation of impacts on selected models												
	3.3: Optimization studies with final version of model												



Table 2. ASCENT Project 106A proposed plan of actions and milestones.

Milestone	Planned Due Date
Literature review and definition of model structure and theory	March 31, 2025
Define experimental “hooks” into the model with Penn State (Experiments planned in coordination with the model)	June 31, 2025
Creation of initial parametric turbine model framework with loss effects from literature – Define boundary conditions from a sample cycle model	December 31, 2025
Year 1 summary report	December 31, 2025
Integration of year 1 experimental results into the model	March 31, 2026
Integrate cooling flow sensitivities	September 30, 2026
Integrate small core impacts and finalize cycle model implementation	December 31, 2026
Year 2 summary report	December 31, 2026
Studies to validate and evaluate impact of the new models	September 30, 2027
Perform alternate turbine design geometry hardware assessments	September 30, 2027
Optimization study with the new model integrated	December 31, 2027
Year 3 summary report	December 31, 2027

While ASCENT Project 106A was ultimately not approved for continuation into Years 2 and 3, the development completed and groundwork laid for increased fidelity parametric turbine modeling will provide the FAA and project partners with a strong stepping stone which can be used to continue turbine modeling work for applications of interest to the FAA and federal government more broadly.

Task 1 - Develop Baseline Models and Turbine Modeling Framework

Georgia Institute of Technology

Objectives

The objectives of this task were to identify best practices for modeling aircraft turbines, and ultimately develop an increased fidelity, parametric modeling framework which could allow users to understand the implications of complex aerothermodynamic losses illustrated in Figure 1, above. Typically, individual losses and complex phenomena have been explored by experimentalists and disciplinary groups, but the collective knowledge of these investigations has not been compiled into a modeling tool which was available for researchers to leverage to understand component and geometry-level impacts of turbines on engine and aircraft scale studies. Task 1 sought to develop a parametric turbine modeling framework which could capture complex effects and the inputs of which could be readily input into engine modeling codes such as NPSS in the form of performance maps and extended to include other capabilities and features.

Research Approach

The development of the baseline modeling framework and a baseline single stage turbine, which could be calibrated to reflect the geometry and produce the performance results of the Penn State START NEXt turbine were pursued through a methodical and systematic process. First, researchers performed an extensive literature review in several main categories to understand several critical components which were important to the framework development process.

After the completion of the initial literature review, a baseline open-source turbine modeling code was found from which to be developed, this code was investigated for missing features which were necessary to include to meet the desired needs and requirements of the parametric turbine modeling framework being developed by Georgia Tech’s ASDL. Upon extensive testing and investigation, several key features were identified to be missing, and those individual features were assigned to researchers and developed throughout the second part of Year 1, with a goal to have them developed and integrated into



the framework before receiving the experimental data from Penn State for calibration and validation. To this end, throughout Year 1, Georgia Tech's ASDL worked with Penn State START Lab members to ensure hooks in the code existed to allow for easy validation and calibration (different datasets) for the baseline modeling framework against the NEXt turbine data. Additionally, bi-weekly meetings with the FAA Technical Advisor were performed with ASCENT Projects 106A and 106B teams, when possible, throughout the period of performance.

Literature Review

As mentioned above, the start of Year 1 was primarily an extensive literature review of over 100 articles and papers was performed to understand the current state of the art with regards to three main categories, which were critical to understanding what the turbine design and analysis code needed to encompass and which loss models and aerothermal effects needed to be included:

1. Current turbine modeling approaches and frameworks (including software)
2. Aerothermodynamic turbine phenomena contributing to efficiency losses and operation
3. Axial turbine design methodologies and approaches

With regards to the first topic, many published papers and turbine modeling codes were identified, obtained, and investigated for appropriateness to the development task outlined as the objective for Year 1. These turbine modeling codes explored include NASA's TURBAN (Glassman, 1994a), TD-2 (Glassman, 1992), Turbo-Design (GitHub, 2025), AXOD (Glassman, 1994b), and open-source codes such as T-AXI (Turner et al., 2025) and Turboflow (Anderson et al., 2025). The exploration of and experimentation with these codes ultimately showed that the Turboflow code developed by Norwegian University of Science and Technology held the most promise for future development, and the most flexibility to be adapted to a fully parametric axial design code which could leverage modern optimization methods. While the available code holds several features which make it more desirable for use than the others (open source, high levels of parameterization, ability to use only simple input datasets if desired, meanline code), it was apparent that it was developed for terrestrial applications when it was found that certain key elements needed to be developed and integrated into the model for aircraft-focused axial turbines (i.e., cooling models and efficiency impacts, size effects, etc.). An investigation into the comparison between modeling fidelity for turbines, from meanline analyses to computational fluid dynamics resulted in the conclusion that a meanline approach was the most appropriate for conceptual level design and allowed for rapid design space exploration and provided a firm foundation for future two- and three-dimensional modeling developments, which were planned for the code.

Additionally, it was important to identify and understand the most recent literature regarding complex turbine phenomena that contribute to operational limitations and losses. As a result, many of the losses seen from the contributing factors, as illustrated in Figure 1, needed to be captured in the turbine modeling framework. This required a sufficient capture of modern literature regarding turbine loss contributors, including those introduced by cooling flows, smaller core geometries, and secondary losses, to name a few. Some significant papers which influenced the development of capabilities in the model include Young and Wilcock (2002) (cooling efficiency and modeling), Young and Horlock (2006) (cooling efficiency and modeling), Tournier and El-Genk (2010) (axial turbine modeling), Sjodin (2019) (meanline method analysis), Lakshminarayana (1970), Kofskey and Nusbaum (1968), (tip clearance effects), Bertini et al., (2013) (loss models and Smith charts), Benner et al. (2006) (secondary losses), Kacker and Okapuu (1982) (cooling efficiency and meanline modeling), and others. As mentioned previously, due to the complex nature of developing turbine models, the literature review which investigated turbine losses continued for the duration of Year 1, as required, to support model development.

Lastly, despite technical leads holding notable experience in turbomachinery analysis, it was important for the team to learn the fundamentals of how turbines are designed, and their resulting performance characteristics, prior to developing complex turbine models in code. Literature in this realm included Gambini and Vellini (2021), Kurzke and Halliwell (2018), Baskharone (2006), Aungier (2006), and others. The initial literature review provided researchers with the necessary understanding to develop their respective component models, and identification of new resources and articles were consistently found throughout Year 1 to support research efforts. Georgia Tech ASDL researchers were required to read selections from Gambini and Vellini and Kurzke and Halliwell to form a common understanding of the object of modeling.

Physics-based Turbine Modeling Framework Development

Although the selected baseline code, Turboflow, held many desirable features, it required modification for the ultimate purposes of being extended to design and optimize aircraft turbines. As mentioned above, several capabilities and the refinement or development of physics-based models to benefit the Turboflow-based design framework being pursued under Task 1 were created and implemented.



1) Cooling Model Development – A study was performed to investigate how to model the performance and calculate the efficiency for a multistage cooled turbine and develop calculations to be incorporated into the Turboflow code. The team ultimately selected to follow the procedure described in *Performance Modeling Methodology: Efficiency Definitions for Cooled Single and Multistage Turbines* (Kurzke, 2002). Due to the fact that Turboflow did not organically incorporate turbine cooling flows in efficiency calculations, a means for adding the necessary intermediate flow stations to perform efficiency calculations and addition of cooling flows was necessary. Illustrations of the conceptual cascade cooling model and modifications to the turbine cascade station numbering can be seen below in Figure 2 and Figure 3, respectively. A key problem which is still being solved by the Georgia Tech ASDL researchers is the ability to effectively model cooling and working fluid flows at the new cascade stations.

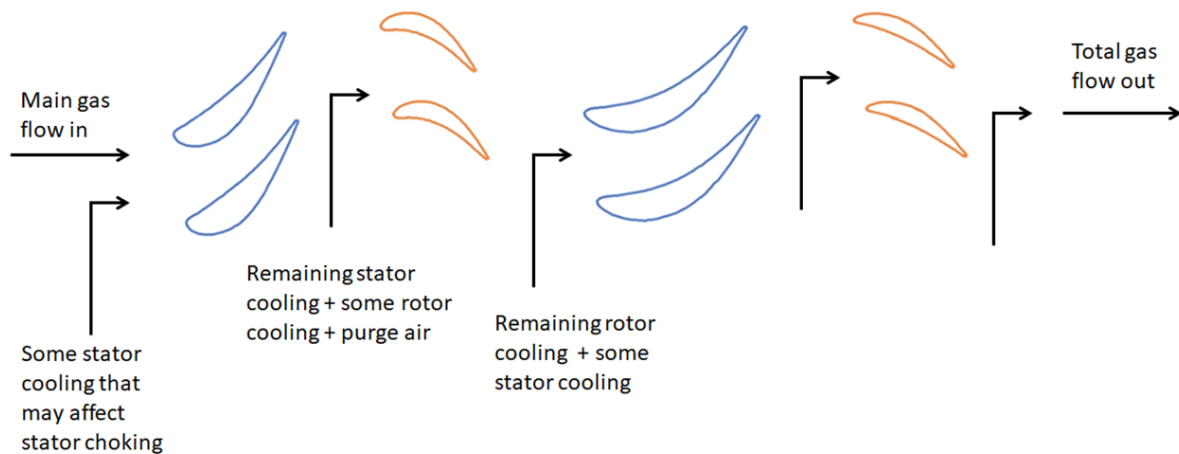


Figure 2. Addition of flows in turbine cascade, seen in cooled turbines.

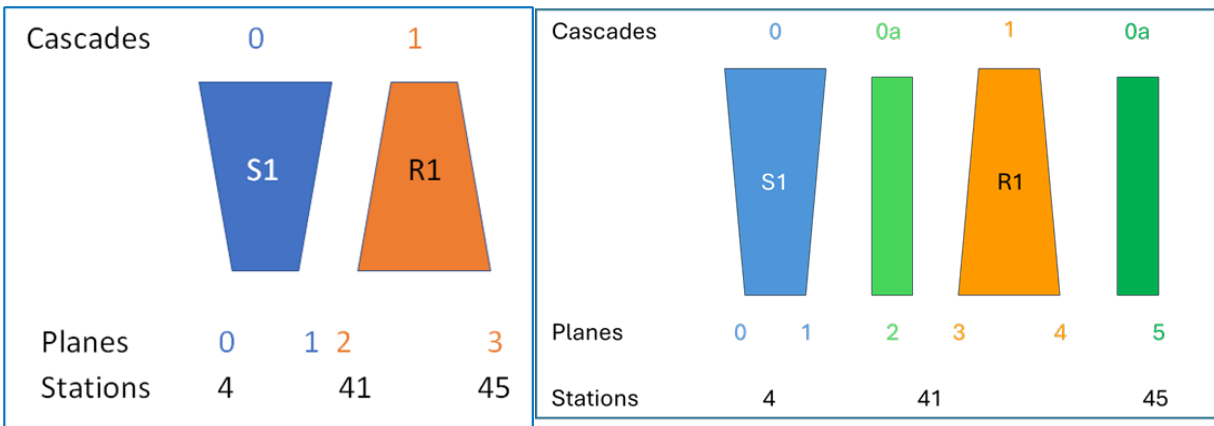


Figure 3. Turboflow cascade numbering (left) vs. modified cascade numbering (right).

Ultimately, the turbine cooling model methodology was developed and is being implemented and validate against Kurzke’s published data as of November of Year 1.

2) Size Effects Study – An investigation into the capability of Turboflow to predict the change in design point efficiency with reduction in the turbine design mass flow yielded mixed results. Using the Kacker-Okapuu loss model (Kacker & Okapuu, 1982), the results appeared to be generally similar to other published data, but using the Benner et al. (2006) loss model produced incorrect and discontinuous trends. Upon further iterations of the study, working to compare Turboflow’s



inherent size effects model against the turbine size effects identified in Bettner (1990), closer similarities were identified between the Turboflow code and published literature. In Year 2, it was intended to attempt to modify Turboflow’s size effects to reflect modern turbine geometries and their performance. A comparison of Turboflow’s performance against the results published in Bettner (1990) are shown below in Figure 4. An important finding from this study includes that the code produces a similar trend, which reinforces the understanding that Turboflow can capture size effects; however, Turboflow is more optimistic for the same turbine design.

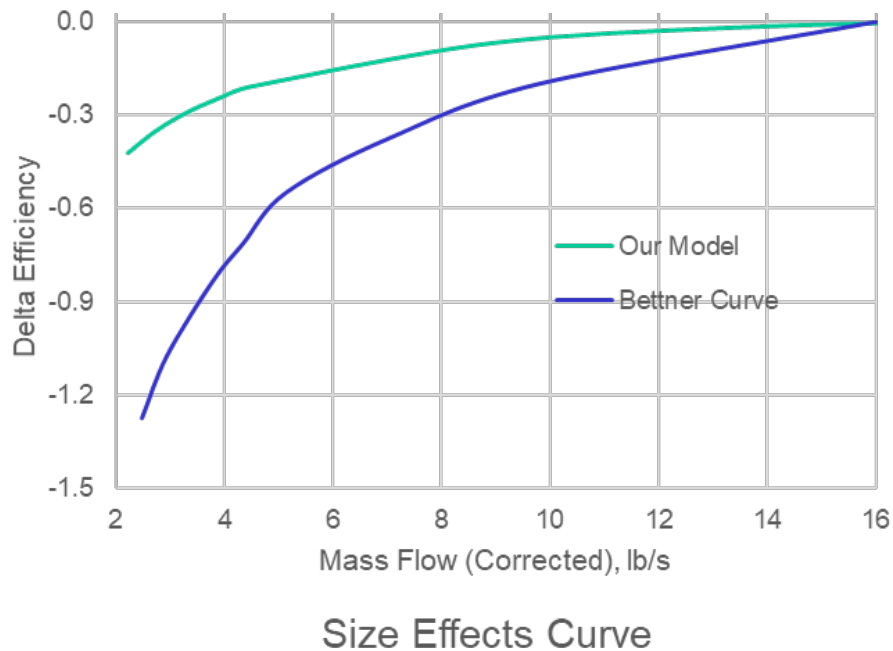


Figure 4. Turboflow size effects compared to Bettner performance.

3) Smith Chart Study – This study was a preliminary investigation of the capability to use Turboflow to reproduce a classical Smith Chart, i.e., a plot of work coefficient vs. flow coefficient with contour lines of constant efficiency, led to realization that a new “geometry tool” to estimate preliminary design geometry must be developed before proceeding with this study to provide the appropriate inputs. The new tool was also expected to help resolve some of the questions raised during the preliminary size effects study described above. Due to the need for a geometry code, that task was pursued before the ability to generate a Smith Chart was realized, and the Smith Chart task was shifted to Year 2. Further progress was made on the preliminary geometry design code and was implemented in the modified Turboflow code to achieve low-fidelity turbine geometry results, but improvements are being pursued for reliability.

4) Disk Design Study – The purpose of this study was to develop a procedure to design a turbine disk using lower-order analytical methods. The disk design is required to provide realistic design constraints for future turbine designs. A finite element method (FEM) approach for disk sizing and analysis has been developed and validated as a standalone code for accurate determination of disk geometry based on allowable stresses for provided geometry types. The analytical code was matched closely to FEM analysis and capable of identifying optimized disk geometries; it was implemented into the Turboflow code to perform disk design in October of the first year.

The capabilities of the code are illustrated by the following figures. Figure 5 illustrates two common disk designs which the code is able to analyze. Figure 6 presents an example of the disk stress analysis results provided by the code. Figure 7 presents an example comparing the temperature prediction results of the code to those obtained with Abaqus, a commercial finite element analysis code.

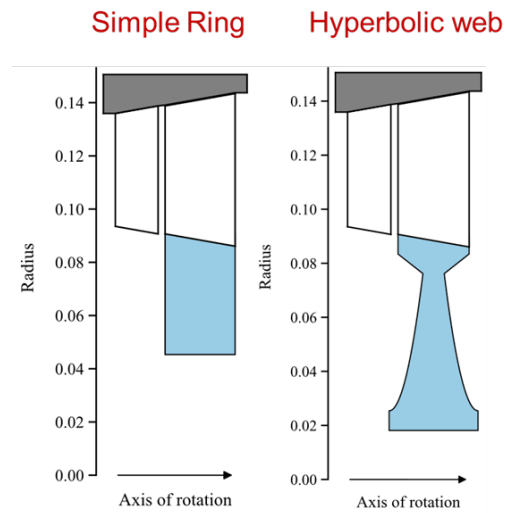


Figure 5. Turbine disk design code geometry design outputs.

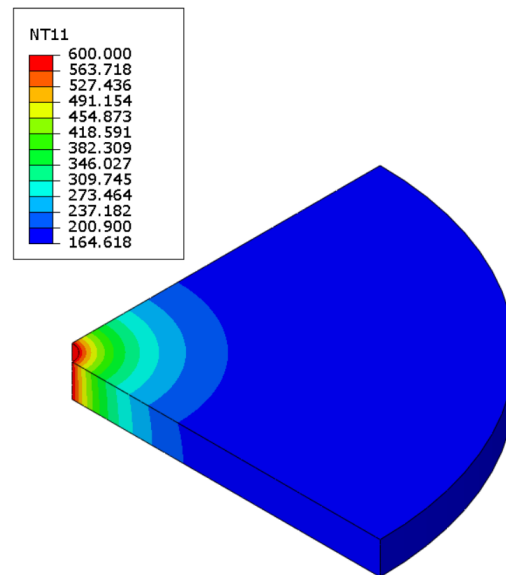


Figure 6. Turbine disk design stress analysis output.

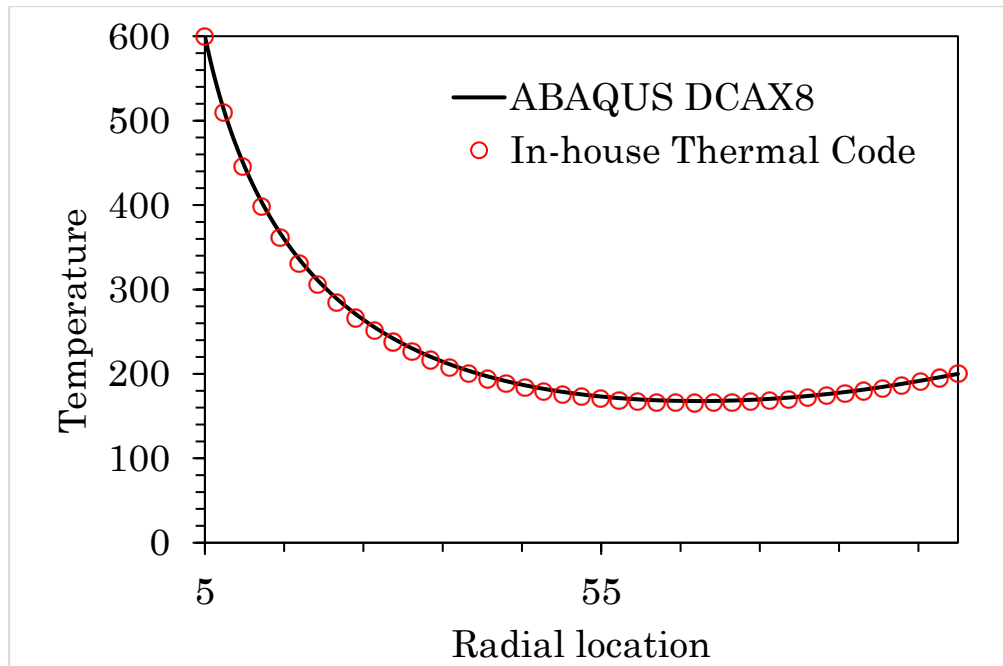


Figure 7. Finite element method vs. Georgia Tech Aerospace Systems Design Laboratory disk thermal stress analysis comparison.

5) Limit Load Study – For this study, Turboflow was examined to understand where turbine loading limits existed for turbine designs with regards to pressure ratios which contribute to the onset of turbine choking. In conjunction with subtask 6, below, Turboflow’s limits for choking were identified as part of the process of developing a turbine map generator to create maps for any given Turbodesign input to the code.

6) Map Generation/NPSS output – The ability to generate new turbine maps representative of new turbine designs was completed and implemented into the Turboflow framework. The subroutine which performs this task allows for the sampling of Turboflow model performance at various rotational speed and turbine exit static pressure combinations. In addition, this code was extended to produce NPSS-format maps for the arbitrary turbine design provided to the Turboflow framework. This functionality was tested with a turbofan model which had been previously developed in NPSS and proven to be successful. An example set of turbine maps can be seen below in Figure 8.

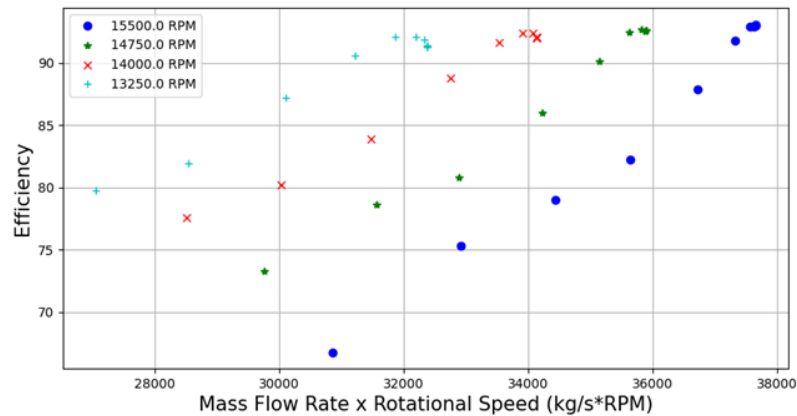
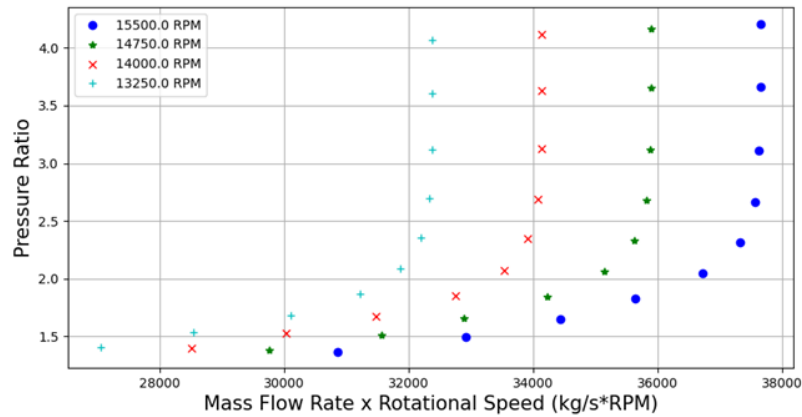


Figure 8. Example turbine maps generated from the new Turboflow map subroutine.

7) **Preliminary Geometry Design Code** – To address the requirements for a Smith chart creation subroutine, a preliminary geometry design code was pursued, seeking to follow the design algorithm outlined in Gambini and Vellini (2021), seen below in Figure 9. The development and integration of this algorithm into the framework is still in progress and incomplete as of the submission of this report but is expected to be completed by the end of the year.

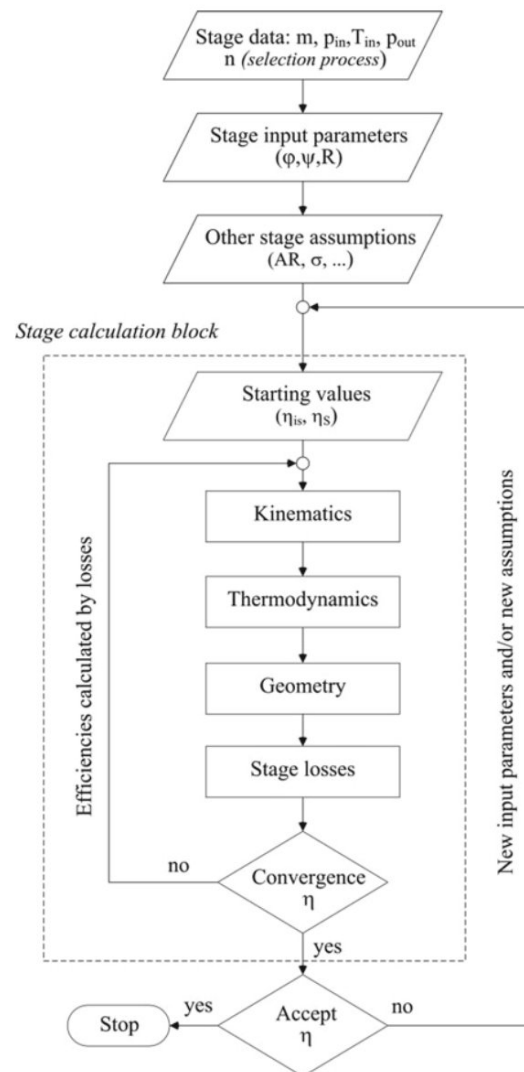


Figure 9. Preliminary geometry design code algorithm (Gambini & Vellini, 2021).

8) Thermodynamics Package Investigation – To support the project extension into the domain of gas turbine engine design and component co-optimization, a Python®-based thermodynamics package which allows for modeling of combustion products was sought in the open literature. Additionally, the desire to model chemical equilibrium was desired for combustion byproduct definition.

9) Integration of Tools into Georgia Tech Turboflow Framework – Upon the completion of the subroutines and their validation and verification, the tools were integrated into the Georgia Tech Turboflow framework for its improvement.

Experimental Data Integration

The researchers at the Georgia Tech ASDL collaborated with Penn State to discuss experimentation plans, using biweekly calls for the purposes of sharing information pertaining to research progress and coordinating future experimentation

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efforts. Penn State and the Georgia Tech ASDL worked on an information sharing agreement to allow the Georgia Tech ASDL access to detailed NExT turbine geometry and performance data for the purposes of validating and training the physics-based turbine model. While NExT turbine geometry data have been requested from Penn State to support the development of a turbine rig-based analytical model for use in the verification and validation for the physics-based M&S tool outlined in Task 1.3, the data transfer took an extended period of time due to legal requirements, and was not usable by the modeling team at the Georgia Tech ASDL for use before the end of the project.

Milestones

Milestones accomplished according to the Table 2 Plan of Actions and milestones is primarily limited to the completion of Task 1.1, the literature review for modeling. Significant work into Task 1.3 took the majority of the effort for the researchers, and the milestone to complete the baseline parametric turbine model is not yet complete, but the tasks accomplished are listed above and below.

Major Accomplishments

Many notable accomplishments were achieved by the Georgia Tech ASDL team in pursuit of completion of Task 1 during Year 1, as the effort comprised the majority of the work defining the Year 1 efforts. The efforts performed in support of completing Task 1 during this year are listed below:

1. Developed disk structural and design modeling code and integrated into Turboflow.
2. Developed cooling flow modeling approach, but integration and validation of the code remain.
3. Surveyed and performed analytical comparison of loss models for capability gap identification.
4. Performed preliminary studies to generate Smith chart.
5. Developed baseline geometry design code, which is still in progress.
6. Performed preliminary exploration of Python-based thermodynamics packages for use with code able to model combustion products for gas turbine modeling.
7. Developed off-design map generation tool and integrated into Turboflow framework.
8. Extended map generation tool to integrate with NPSS cycle modeling code and related limit load study.
9. Performed size effects modeling study to understand Turboflow limitations with regards to modeling reduced core size turbines.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

The following graduate students were involved in ASCENT Project 106A:

- Anand Iyer—Worked to identify turbine loss models and code development
- Niharika Akula—Developed turbine disk structural modeling and optimization code
- Esteban Pais—Assisted in the completion of the turbine cooling methodology identification
- Sindhu Belki—Performed turbine size effects modeling and analysis
- Jessica Tang—Worked on turbine modeling framework development and preliminary geometry modeling capability. Worked to connect the Turboflow meanline modeling code to the two-dimensional streamline code Turbo-Design (GitHub, 2025) for Master's Special Problem topic

The following undergraduate students (not funded) were involved in ASCENT Project 106A:

- Charles Howard—Task 1, Developed alternate cooling modeling approach, which is currently being verified for functionality
- Ethan Cordeiro—Task 1, Assisted with the turbine loss model literature review



Plans for Next Period

The project will end at the end of this period of performance; as a result, plans for following years of work will not be pursued.

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