AIAA Foundation Student Design Competition 2022
Undergraduate Team – Engine

Special Edition for 2022

Option 1

Option 2

- Request for Proposal -

January 31, 2022

Abstract

This year, AIAA discontinued the Propulsion and Energy Forum in August and transferred most of its gas turbine engines content to the SciTech Forum in January for sound business reasons. This meant that the regular August venue for Round 2 of the Engine Design Competition was eliminated and this has caused us to revise the normal schedule for the Engine Design Competition – a task still in progress! A great deal of time has been lost, so in order to ensure that a topic is available in 2022 for senior capstone courses and with the hope of keeping the competition alive, we offer a special RFP without the need to generate a new one from scratch.

In this year's RFP, undergraduate teams are invited to select one topic from two fairly recent existing RFPs, cited as *References 1* and *2*.

The options offered are:

1. *An Ultra-High Bypass Ratio Turbofan Engine for the Future*

2. *Let's Re-Engine the Concorde!*

Proposal requirements have been made more rigid to correspond more closely with activities that take place in preliminary engine design in industry. In pursuit of these objectives, additional detailed directions are provided and tutorials will be available for participating teams and their advisors.

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1. Introduction

Background, specific design objectives, and the baseline engine models for the two RFP options are provided in References 1 and 2.

2. Design Objectives & Requirements

This competition is intended to simulate a preliminary design project in industry. The objectives there are

- To conduct a broad study of a large number of engine designs using cycle and performance studies in order to determine how to focus the remainder of the program
- To select a smaller number of candidates for a closer look via more detailed design by estimating component & overall weights & dimensions, sizing disks with acceptable stress margins, calculating moments of inertia for the rotating assemblies, and assessing the overall feasibility of the concept (Does it fit together and operate?)
- Weight (more correctly mass) can then be traded against performance and fuel burn
- The best "compromised" solution is then selected as the best candidate for detailed design work and confidence is established on which to investment company resources

At this point, the budget is extremely tight and the risks are very high. No one is prepared to extend the exercise beyond 0-D (cycle studies) and 1-D (meanline studies). Nothing has been generated in 3 dimensions. Even though the capabilities exist to produce elaborate 3_D assembly drawings, these are inappropriate because nothing has been designed in 3-D yet, and CFD is certainly not applicable. Frequently, a new derivative engine is required, so certain components already exist, maybe as a simulation of model or possibly even as actual hardware. These will be used later in the overall engine project, so don't go designing stuff if you are told not to! In the RFP, you are not being asked to demonstrate how much you know; you are being asked to apply only a certain amount of it and to focus that knowledge on the project in hand. The intention of the RFP is to provide a vehicle to help you learn and build confidence in applying important propulsion fundamentals.

Teams are limited to 4 people. This allows all team members to experience all aspects of the project fairly closely, while focusing on a specific part of it themselves – teamwork in action! To enable the project to be completed within a reasonable period, the project is deliberately restricted to preliminary design. Two people can probably handle the work; if there are 6, 7 or 8 people who wish to participate, you have 2 teams! We can make an exception on team head count to accommodate an additional member. Just ask.

Now let us look at a few specific aspects of the two RFP options.

2.1 Option 1: An Ultra-High Bypass Ratio Turbofan for the Future

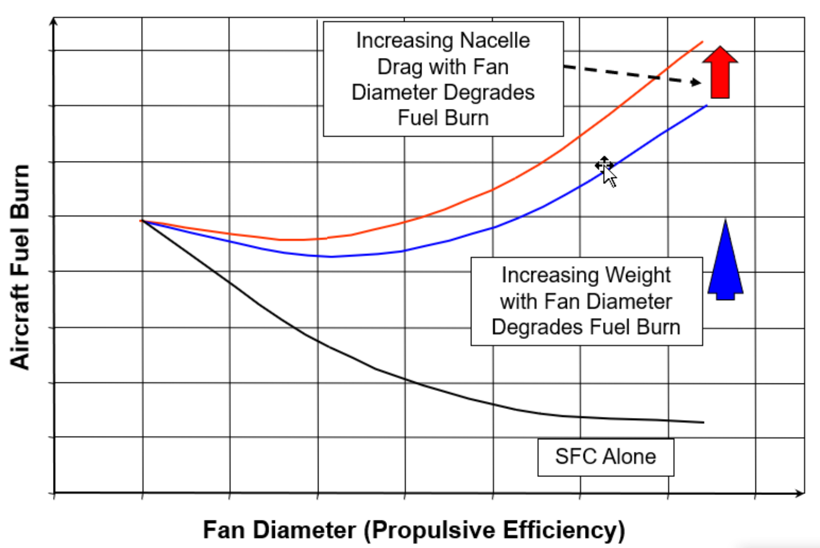
In this option, we address a derivative engine. We want to know the potential for thrust growth and SFC improvement in the baseline engine which has been provided, while retaining the core, namely the HP compressor, the combustor and the HP turbine. They already exist as hardware –

their geometry must be left unchanged in the design of your new engine. The original turbofan core was intended to permit growth within an *engine family*, where the role of the HP compressor is especially important here. New HP compressors are quite rare and each is the result of a massive and expensive development program. The company can now make some money by exploiting that investment further! Service entry for the derivative engine is 2030, 15 years after the baseline, so some new technology is available - advanced materials and efficiency improvements.

The task becomes an exercise in re-designing the IP and LP spools. How high may we go on bypass ratio? What is the best work split between the fan and the IPC? How do fan pressure ratio and bypass ratio interact? How do we set up the similar entry conditions into the HP compressor, despite all the differences happening upstream? Do we really need 3 shafts? Do we gain or lose weight if we change that? How many LP turbine stages do we need? How does that affect weight and performance? Is additional cooling or new materials required? And the big question – what about a gearbox? Does that open the door to a 2-spool system?

You are expected to calculate SFC and weight and assess their combined effect on mission fuel burn (but you may disregard the drag due to changes to the nacelle). You must show the overall dimensions with a general arrangement and evaluate the feasibility of the components, both aerodynamically - using velocity diagrams - and mechanically - with a preliminary stress check on the disks. You should identify advances in technology you assumed compared to the baseline.

The turbine entry temperature, T4 must be increased to permit higher bypass ratios to be achieved, so we will not limit T4 or T41; you should investigate how large a bypass ratio is made available by raising T4 and T41. In theory, SFC continues to fall as as bypass ratio rises, but there is a limit in practice at the point where drag imposes too high a penalty. This is illustrated in the figure below.



Finally, a valuable tip for any turbofan engine; setting V18/V8 to be roughly 0.8 results in minimum SFC!

Can you minimize your matrix of candidate engines to give you the answers you need, remembering that all your designs must be worked to the same standard and the same mission flown to give you equable comparisons?

2.2 Let's Re-Engine the Concorde!

Replacing the Olympus 593 is a different exercise. It covers a range of subsonic and supersonic fight speeds. The 593 technology is ancient, so how hard can it be? Component performance maps are introduced into this project, therefore if you have never used maps before, now is your chance to learn. Again, a planned design matrix is necessary to determine roughly where your best candidate engine may lie. Engine size is a major restriction, since it must fit in the existing nacelle. No, we are not going to re-design the Concorde! And, as stated in the RFP, we already have a perfectly good inlet, except for a materials update – so stay away from that! And don't redesign the burner nor look too hard at secondary systems – oil, fuel, air, etc.; there are special departments outside of Preliminary Design who do that sort of thing.

The same general approach outlined in RFP Option 1 should be used here. Stay with preliminary design; no 3-D plots, no matter how pretty they look, they are meaningless here and, with a small team, you don't have time for CFD (In industry, you wouldn't get fired for it, your boss might because you blew the budget and he let you do it!)

Finally, for either RFP option, generate an over/under plot of your new engine versus the baseline engine so a clear graphical comparison is possible.

It is recommended that teams who know that they will enter the competition inform AIAA and Dr. Ian Halliwell (ianhalliwell@earthlink.net) as soon as possible, so that assistance may be given and access to design codes may be arranged, where appropriate.

A short series of informal tutorials will be arranged for interested teams and advisors. The agenda will be set by whatever you want to talk about. Contact information will be provided to teams who submit a *letter of intent.*

3. Competition Expectations

The existing rules and guidelines for the *AIAA Foundation Student Design Competition* should be observed and these are provided in *Appendix 2*. In addition, the following specific suggestions are offered for the event.

This is a preliminary engine design. It is not expected that student teams produce design solutions of industrial quality, however it is hoped that attention will be paid to the practical difficulties encountered in a real-world design situation and that these will be recognized and acknowledged. If such difficulties can be resolved quantitatively, appropriate credit will be given. If suitable design tools and/or knowledge are not available, then a qualitative description of an approach to address the issues is quite acceptable.

In a preliminary engine design, the following features must be provided:

- Definition and justification of the mission and the critical mission point(s) that drive the candidate propulsion system design(s).

- Clear and concise demonstration that the overall engine performance satisfies the mission requirements.

- Documentation of the trade studies conducted to determine the preferred engine cycle parameters such as fan pressure ratio, bypass ratio, overall pressure ratio, turbine inlet temperature, etc.

- An engine configuration with a plot of the flow path that shows how the major components fit together, with emphasis on operability at different mission points.

- A clear demonstration of **design feasibility**, with attention having been paid to technology limits. Examples of some, but not all, velocity diagrams are important to demonstrate viability of turbomachinery components.

- Stage count estimates, again, with attention having been paid to technology limits.

- Estimates of component performance and overall engine performance to show that the assumptions made in the cycle have been achieved.

Credit will be given for clear descriptions of how any appropriate upgrades would be incorporated and how they would affect the engine cycle.

Each proposal should contain a brief discussion of any computer codes or *Microsoft Excel* spreadsheets used to perform engine design & analysis, with emphasis on any additional specific features generated by the team.

Proposals should be limited to fifty pages, which will not include the administrative/contents or the "signature" pages.

References

1. *"An Ultra-High Bypass Ratio Turbofan Engine for the Future"*
   AIAA Foundation Student Design Competition: A Special RFP for 2022

2. *"Let's Re-Engine the Concorde!"*

Suggested Reading

1. "*A History of the AIAA Undergraduate Engine Design Competition – Its Purpose, How to Write an RFP and How to Win*"
   Ian Halliwell
   AIAA Propulsion and Energy Forum New Orleans, 2020.

Available Software

"NPSS® Academic Edition (www.npssconsortium.org): Numerical Propulsion System Simulation® (NPSS®) proudly sponsors the AIAA Undergraduate Engine Design Competition, with the hope to help students develop valuable skills for the aerospace industry. An academic version of the NPSS software is available for free to all students throughout the world. NPSS is the industry standard for aerospace engine cycle design, analysis, and system integration. Primary applications include aerospace systems, but it can also be used for modeling rocket propulsion cycles, Rankine and Brayton cycles, refrigeration cycles, and electrical systems. A copy of the newly released NPSS Integrated Development Environment (IDE) is available for students participating in the AIAA Undergraduate Engine Design Competition." ***NPSS®***

GasTurb14 is a comprehensive code for the preliminary design of propulsion and industrial gas turbine engines. It encompasses design point and off-design performance, based on extensive libraries of engine architectures and component performance maps, all coupled to impressive graphics. A materials database and plotting capabilities enable a detailed engine performance model to be generated, with stressed disks and component weights. A student license for this code is available directly strictly for academic work. A free 30-day license may also be down-loaded. **(http://www.gasturb.de)**

AxSTREAM EDU™ by SoftInWay Inc. **(http://www.softinway.com)** AxSTREAM® is a turbomachinery design, analysis, and optimization software suite used by many of the world's leading aerospace companies developing new and innovative aero engine technology. AxSTREAM EDU™ enables students to work on the design of propulsion and power generation systems. AxCYCLE™, an add-on to AxSTREAM EDU™ addresses cycle design and analysis. Participants in the AIAA Undergraduate Team Engine Design Competition can acquire an AxSTREAM EDU™ license via the following steps:

- Submit a Letter of Intent to AIAA
- Once the letter of intent has been received and approved, names of team members will be recognized as being eligible to be granted access to the AxSTREAM EDU™ software by AIAA.
- Students must then contact the AIAA Student Competition Chair, listed with the abstract, who will then arrange for SoftInWay to grant the licenses.

In addition to the software, students will also gain free access to STU, SoftInWay's online self-paced video course platform with various resources and video tutorials on both turbomachinery fundamentals.

The offers above are subject to *ITAR* restrictions.

Appendix 1. Proposal Information

2022 AIAA Foundation Undergraduate Team Engine Design Competition

To be eligible for the 2022 AIAA Engine Design Competition for Undergraduate Teams, you must complete the team roster and proposal information form located at www.aiaa-awards.org. This information must be submitted by **March 1, 2022 by 2359hrs US ET.** If you have any questions about the process for submitting this information, please direct your question to studentprogram@aiaa.org.

Appendix 2. Rules and Guidelines

I. General Rules

1. All undergraduate AIAA branch or at-large Student Members are eligible and encouraged to participate.

2. Teams will be groups of **not more than four** AIAA branch or at-large Student Members per entry.

3. An electronic copy of the report in MS Word or Adobe PDF format must be submitted electronically to AIAA Student Programs. Total size of the file(s) cannot exceed 60 MB, which must also fit on 50 pages when printed. The file title should include the team name and/or university. **A "Signature" page must be included in the report and indicate all participants, including faculty and project advisors, along with their AIAA member numbers**. Designs that are submitted must be the work of the students, but guidance may come from the Faculty/Project Advisor and should be accurately acknowledged. **Graduate student participation in any form is prohibited**.

4. Design projects that are used as part of an organized classroom requirement are eligible and encouraged for competition.

5. More than one design may be submitted from multiple teams of students at any one school.

6. If a design group withdraws their project from the competition, the team chair must notify AIAA Headquarters immediately.

7. Judging will be in two parts.
   - First, the written proposals will be assessed by the judging panel comprised of members of AIAA organizing committees from industrial and government communities.
   - Second, the best three teams will be invited to present their work to a second judging panel at a special virtual session to be arranged in, August 2022. The results of the presentations will be combined with the earlier scores to determine first, second and third places.

8. Certificates will be presented to the winning design teams for display at their university and a certificate will also be presented to each team member and the faculty/project advisor. The finishing order will be announced immediately following the three presentations. Unfortunately, funding for monetary prizes is unavailable this year due to the disruption in our schedule.

II. Copyright

All submissions to the competition shall be the original work of the team members.

Any submission that does not contain a copyright notice shall become the property of AIAA. A team desiring to maintain copyright ownership may so indicate on the signature page but nevertheless, by submitting a proposal, grants an irrevocable license to AIAA to copy, display, publish, and distribute the work and to use it for all of AIAA's current and future print and electronic uses (e.g. "Copyright © 20__ by _____. Published by the American Institute of Aeronautics and Astronautics, Inc., with permission.).

Any submission purporting to limit or deny AIAA licensure (or copyright) will not be eligible for prizes.

III. Schedule and Sequence of Activities

Significant activities, dates, and addresses for submission of proposal and related materials are as follows:

A. Letter of Intent – March1, 2022
B. Receipt of Proposal – June 1, 2021
C. Proposal evaluations completed - July 1, 2022
D. Round 2 Proposal Presentations & Announcement of Winners at a special virtual session; date to be decided, in August 2022.

Teams intending to submit a proposal must submit a one page Letter of Intent along with the signed attached Intent Form (Item A) on or before the date specified above, to:
Michael Lagana, AIAA University Programs Manager at StudentProgram**@aiaa.org.**

A pdf file of the proposal must be received at the same address on or before the date specified above for the Receipt of Proposal (Item B).

IV. Proposal Requirements

The technical proposal is the most important criterion in the award of a contract. It should be specific and complete. While it is realized that all of the technical factors cannot be included in advance, the following should be included and keyed accordingly:

1. Demonstrate a thorough understanding of the Request for Proposal (RFP) requirements.

2. Describe the proposed technical approaches to comply with each of the requirements specified in the RFP, including phasing of tasks. Legibility, clarity, and completeness of the technical approach are primary factors in evaluation of the proposals.

3. Particular emphasis should be directed at identification of critical, technical problem areas. Descriptions, sketches, drawings, systems analysis, method of attack, and discussions of new techniques should be presented in sufficient detail to permit engineering evaluation of the proposal. Exceptions to proposed technical requirements should be identified and explained.

4. Include tradeoff studies performed to arrive at the final design.

5. Provide a description of automated design tools used to develop the design.

Proposals should be submitted to www.aiaa-awards.org

V. Basis for Judging

Round 1: Proposal

1. Technical Content (35 points)
This concerns the correctness of theory, validity of reasoning used, apparent understanding and grasp of the subject, etc. Are all major factors considered and a reasonably accurate evaluation of these factors presented?

2. Organization and Presentation (20 points)
The description of the design as an instrument of communication is a strong factor on judging. Organization of written design, clarity, and inclusion of pertinent information are major factors.

3. Originality (20 points)
The design proposal should avoid standard textbook information and should show independence of thinking or a fresh approach to the project. Does the method and treatment of the problem show imagination? Does the approach show an adaptation or creation of automated design tools?

4. Practical Application and Feasibility (25 points)
The proposal should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or insolvable problems.

Round 2: Presentation

Each team will have 30 minutes to present a summary of its proposal to the judging panel. In addition to the categories above, the presentations will be assessed for clarity, effectiveness and the ability to sell the teams' ideas. Scores from the presentation will be added to those from the proposal. The presentation score will be adjusted so that it is worth 30% of the overall value.