**AE 721 Report 10 Required Contents**

**Due Monday 4 December 2023 9am**

by e-mail to <kuaerodesign@gmail.com>  
AE721\_Report10\_TeamName.docx *example: AE721\_Report10\_Jayhawkers.docx*

AE721\_Report10\_ TeamName.pdf *example: AE721\_Report10\_Jayhawkers.pdf*

**Team Assignment**

Note that the work to be performed for this report is to be done by Teams of students.

**Total Points:** 50

What follows is a specification for the minimum required contents report. Your report must be organized in this manner. You may, within each section, add sub-sections if you so desire. Each chapter must start with a statement of purpose, except the Introduction and the Summary/Conclusions chapters.

**Report Title: AE 721 Report 10 RAIDER Weapon System Design**

**Cover** - This is a good idea for both the .doc and .pdf files as it will be necessary when the file is printed to a hard copy. Name all team members.

**Title Page -** This page should be the first page of the report (if a cover is used, then it will be within the cover page). This page should be numbered as page "i."

**Acknowledgments –** Optional, make them real. Thank Mom/Dad/HS Teachers/Pets as you feel appropriate.

**Table of Contents -** The table of contents shall be structured as follows:

**Table of Contents** page

List of Symbols iii

Acknowledgment iv

1. Introduction 1

2. Chapter 2 Major Heading 3

2.1 Chapter 2 First Section 3

2.2 Chapter 2 Second Section 5

2.2.1 Chapter 2 First Subsection of Second Section 5

etc.

**Page Numbering -** The first section of the report containing the list of symbols, acknowledgment, list of tables and list of figures etc. shall be numbered with lower case Roman numerals. The body shall be numbered sequentially with Arabic numerals 1, 2, 3, etc. The Appendices shall be numbered with the letter of the appendix first followed by a dash and a page number: A-1, A-2, A-3; B-1, B-2, B-3 etc.

**List of Symbols -** You must include any symbols that are used in this report. You must give the names of the symbols and the units. After the main body of the symbols, you should include Greek symbols, then subscripts, followed by acronyms.

**List of Figures -** List any and all figures that are found in the report along with the page they are found on.

**List of Tables -** List any and all tables that are found in the report along with the page they are found on.

**Notes on Generated Codes and Plots**

Any suitable code may be used (like Excel, MatLab, other coding language). The original code must be turned in with the homework.

**Notes on Previous Work**

Include write-ups and technical work from previous assignments. Correct any mistakes made in the new report to be turned in. Note that if an error is flagged in an earlier report and it is not corrected in a later report, twice the number of points will come off.

**1. Previous RAIDER Work**

Review the past work done during the semester on the RAIDER configuration, summarizing the bulk of Report 6 and before. Include photos of your model missile (it’s alright if the team is in it). For the BASS team, summarize observations of others on the RAIDER (it will be short) and opine on the making of a 155mm BASS-RAIDER.

**2. General RAIDER Layout**

Make a generalized schematic of your RAIDER. AIM-120, AIM-9, 155mm NAMMO, and 105mm NAMMO teams, draw a line drawing of your RAIDER including a quasi-isentropic inlet, side ducts, combustor inlet throat, combustion chamber in the tail stock and converging-diverging nozzle. The BASS-RAIDER team should include a conventional BASS round with a quasi-isentropic inlet, side ducts, combustor inlet throat, combustion chamber in the tail stock and converging-diverging nozzle with an expansion bell, expanding to at least 10% more than the main body diameter. Be sure to mark each point just the same as Fleeman shows in his Fig. 3.24 as well as following figures. Make sure your schematic LOOKS like your RAIDER variant (rather than Fleeman’s idealization below).

A diagram of a fire extinguisher

Description automatically generated

The BASS-RAIDER team needs to do the same, but include a line drawing before, during and after sabot separation, before ramjet duct inflation and after ramjet duct and expansion bell inflation.

**3. Fight Assumptions and Mission Profile**

For each design, each team will assume that the missile will be accelerated to Mach 4 by an expulsion charge and/or rocket motor before RAIDER engagement. At Mach 4, the RAIDER will be deployed. NAMMO 105 and 155mm and BASS-RAIDER teams will assume a Mach 7 barrel exit and trade KE for PE, leveling out at Mach 4 with the NAMMO rounds losing 50% of muzzle kinetic energy once it reaches Mach 4. The BASS-RAIDER round will only lose 10% of the muzzle KE by the time it reaches a higher altitude at Mach 4. Assume the 105 and 155mm NAMMO RAIDER designs will be launched at sea level from a static gun. Assume the BASS-RAIDER is launched at 55,000 ft, Mach 0.75 FAC-17 cruise conditions (+Mach 7 muzzle velocity). The NAMMO rounds will wind up around 70,000 ft, the BASS-RAIDER will top out around 180,000 ft. The AIM-120 and AIM-9 can rely upon a rocket launch taking the missile up to at least 80,000 ft with rocket motor burnout at Mach 4. Calculate the altitudes for all RAIDER configurations, considering a Mach 4 motor burnout/apogee.

**4. RAIDER Design for Mach 4 at Burnout Altitude, Cruise Initiation Point**

Considering the conditions of burnout of Chapter 3, begin laying out the RAIDER engine.

4.1 Determination of required thrust at Cruise Initiation Point

From earlier homeworks and new work, determine the amount of thrust needed at the prescribed altitude determined in Chapter 3, considering Mach 4 flight. Calculate cruise angle of attack, L/D, weights as necessary.

4.2 Assumptions

Make reasonable assumptions for all areas, pressures and temperatures with Fleeman helping guide the estimations. List them here as the start of the first design iteration.

4.3 Calculate Ao and AIT

Using Figure 3.28, assuming initially a stoichiometric fuel-air ratio, calculate Ao at Mach 4 and the altitude calculated above. If Ao is larger than the major area of the missile, assume Ao is the major area of the missile. Calculate by assuming no spillage at the inlet area, Ao and by including the effects of fuel in the flow.

Assume inlet start Mach number, M1E, begins at Mach 1.5. Using the 2nd equation on p. 186, calculate AIT and the inlet is a quasi-isentropic compression spike.

4.4 Calculate Combustor Inlet Mach number, M3, Combustor Inlet Area, A3, Combustor Exit Mach Number, M4 and Pressure, P4

Assuming a given value for T4/T0, at Mach 4, from Fig. 3.30, determine M3. From Fig. 3.29 and/or the first equation in Section 3.13, get A3. Using the expressions on p. 172 and 173, manifested in Fig. 3.31, determine M4 and P4.

4.5 Calculate Speed of Sound in Combustion Chamber

Using T4 and an estimate for ratio of specific heats, calculate the speed of sound in the combustion chamber, a4.

4.6 Calculate Combustion Speed, V4

With a4 and M4 in hand, estimate combustion chamber speed, V4.

4.7 Calculate Combustion Chamber Length, Lc

Given V4 and assuming typical combustion times described on p. 173, determine the length of the combustion chamber.

4.8 Determine Throat Area

Given combustion chamber flow properties, estimate the throat area for sonic choking. Get, . Assume c\* at a nominal value of 5,200 ft/s. Using the combustion chamber pressure, pc = p4 and Figure 3.53, determine the throat area, At. Make sure your units line up with respect to mass and weight flows.

4.9 Design the Expansion Bell/Nozzle

If the munition being designed is the BASS-RAIDER, assume the expansion bell goes to 1.1x the projectile diameter. All others, assume the expansion bell goes to the outer mold line of the baseline missile. Examine engines like an F-1 to approximate a good shape and draw the profile of the expansion bell from the throat to the end of the nozzle. (Of course, the real way to design this is by “Method of Characteristics” which is typically covered in a Compressible Flow class.)

4.10 Determine Engine Thrust and ISP

By using the estimations contained in this chapter and new design considerations, determine the engine thrust and Isp by using the techniques laid out in Fleeman.

**5. Design Iteration and Optimization**

Using the methods described in Chapter 4, iterate about the design. Change areas, duct geometries, throat geometries, expansion bells and any other characteristics as you see fit. Consider shape-changing materials that are “unusual” for aerospace applications, as well as inflatable, reticulated ducts as you see fit. Close on a solution that, with development, would be workable and feasible. Describe in brief the start point for each iteration including a CAD if available. Describe what was done and/or changed in a few sentences and the end point with data and a CAD. Perform at a minimum 5 iterations towards closure. Work to optimize the design, minimizing complexity, weight, ISP and cost.

**6. Final RAIDER Weapon CAD Figures**

With the final configuration of the RAIDER, CAD up three variants of your weapon system. Include: a.) fully CADDED, 4-view (front, top, side and iso.), b.) a full color cut-away of the weapon with labels showing what’s what in each area in an isometric view.

1. Fully collapsed/stowed – show the weapon in the tube launch configuration with all extra rocket motors and/or expulsion charges and/or the full cartridge;
2. Separated, just post launch and/or burn-out – show the weapon just after the expulsion charge burns out and/or the boosting rocket motor burns out or drops off, all ducts and control surfaces are in the stowed positions;
3. Dash and terminal configuration – show all ducts, expansion bells, control surfaces and any other item in their fully deployed configuration.

Note that there will be a total of 15 separate figures shown for full credit (5 for a & b x 3 configurations = 15).

**7. Summary, Recommendations and Section Responsibilities**

**7.1 Summary**

Summarize all technical data for the engine and RAIDER configuration above. Bulletize and place information in table(s) as appropriate.

**7.2 Recommendations**

Make constructive recommendations, especially for Report 10.

**7.3 Section Responsibilities**

Write down all team members’ names and list the section(s) they helped with. Describe each team member’s contributions to each section listed by their name.

**References**

As laid out in Report 1.

**Appendices:** Include as much information as the team deems relevant in one or more appendices. Make sure to include the appendix number and name in the Table of Contents, but not its page numbers. Note that appendices are stand-alone documents with page numbering like A-1, A-2, A-3… etc.

**AE 721 Presentation Report**

**Due Wednesday 6 December 2023 9am**

by e-mail to <kuaerodesign@gmail.com>  
AE721\_Presentation\_TeamName.mp4 *example: AE721\_Presentation\_Jayhawkers.mp4*

*AND*

AE721\_Presentation\_TeamName.pptx *example: AE721\_Presentation\_Jayhawkers.pptx*

**Team Assignment**

Note that the work to be performed for this report is to be done by Teams of students.

**Total Points:** 100

Assemble the following in PowerPoint, turning in the PowerPoint file itself as well as the .mp4 recording of the presentation

**Report Title: AE 721 Presentation, Team “x”**

**Title Page -** This page should be the first page of the report (if a cover is used, then it will be within the cover page). This page should be numbered as page "i."

**Acknowledgments –** Optional, make them real. Thank Mom/Dad/HS Teachers/Pets as you feel appropriate.

Make sure that every team member gets roughly the same amount of time. Not every team member has to speak for each section, but they need to be seen and heard.

1. **Overview of the Semester-long Team Project –**

Describe the team project, how it progressed. Use Report 10 (and earlier reports if you choose) to form an outline.

1. **Technical Goals, Mission Specification and Profile**

Deliver top-level information on the team project including goals, mission spec. and profile.

1. **Analysis Methods Used**

Describe Fleeman’s methods for sizing and layout (which are all empirical and 1-d physics based).

1. **General Layout and Flow Modeling**

Describe your weapon system layout and the flow modeling through the weapon system.

1. **Overall Performance**

Describe thrust, Isp, fuel flows, etc. etc. as well as the multiple configurations the weapon system can have.

1. **Anatomy**

Describe the weapon system anatomy and present any and all CAD figures you generated with proper labels, describing to the reader what’s what, how it functions, pressures, temperatures etc. at each station

1. **Conclusions and Recommendations**

**7.1 Conclusions**

Describe the overall performance numbers and geometries. Include comments comparing your weapon system to the state of the art.

**7.2 Recommendations and Future Work**

Describe what the team recommends for changes and/or future work. Include any comments about shape-changing structures, and technical feasibility.

1. **Field Trip to NDIA Symposium**

Describe the overall field trip to the symposium, days, duration, who flew, who drove, what was learned. Include picts of the team in the booth and individuals in the exhibit hall (please no bar picts or the like).

**References (as appropriate)**