UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE of ENGINEERING
Industrial Solutions Laboratory

Company Information

Company Name	*NAVAIR* **FRC East CP MRO Engineering**	**Date Submitted**	*05/24/2021*
Project Title	*Development of a Mechanical Method of Measurement for the F402 (Harrier) Hot Nozzle* **(NAV_F402)**	**Planned Starting Semester**	*Fall 2021*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills:

Discipline	Number	Discipline	Number
Mechanical	3	Electrical	1
Computer	1	Systems	
Other ( )			

Company and Project Overview:

For more than 60 years, Fleet Readiness Center East, at Marine Corps Air Station, Cherry Point, N.C., has played an integral role in our national defense. The facility's In-Service Support Center provides multi-disciplinary, engineering services in both design and maintenance. Our workforce has earned a reputation of excellence, providing worldwide support for Navy and Marine Corps aviation.

Fleet Readiness Center East has provided maintenance, repair, and overhaul support to virtually every weapons platform the Marine Corps has flown – from the inverted gull-winged F4U Corsair of World War II fame, to the Corps newest aircraft, the F-35B Lightning II. It is one of eight fleet readiness centers operated by the United States Navy. It is also the Department of Defense Vertical Lift Center of Excellence. FRC East has a workforce of about 3,800 civilian, military, and contractor personnel. It is North Carolina's largest industrial employer east of Interstate 95. NAVAIR is an active employer for UNC Charlotte grad's and has many COE Alum's on their staff.

FRC East artisans perform phased depot maintenance, planned maintenance intervals, integrated maintenance concepts, modernizations, conversions, overhaul or in-service repair on the AV- and TAV-8B Harriers, the V-22 Osprey, the AH-1W Super Cobra, the AH-1Z Viper, the UH-1N Huey, the UH-1Y Venom, the CH-53E Super Stallion, and MH-53E Sea Dragon, the F/A-18 Hornet, the F-35B Lightning II, the H-3 Sea King; the H-60 Seahawk; the EA-6B Prowler; and the C-130 Hercules. The depot is also the depot repair point for the drive and rotary systems of the MQ-8B Fire Scout.

This project is intended to develop a replacement metrology method for engine measurement.

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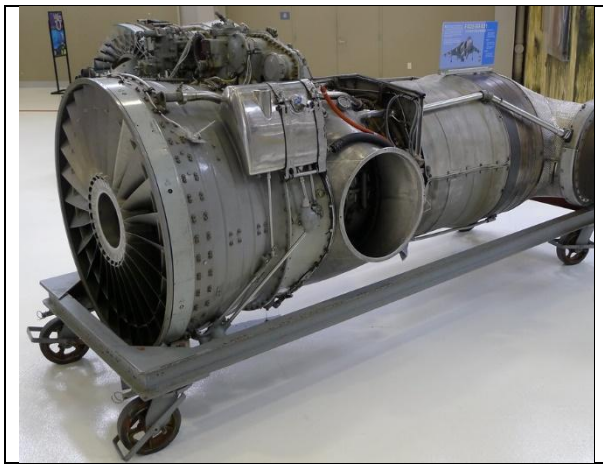
Project Requirements:

FRC East CP is the Maintenance Repair and Overhaul Facility for the F402 Engine which is used on the AV-8B Harrier Aircraft.



One of the parts of the Engine is the Hot Nozzle, Part Number B510204, which controls the direction of thrust. The proper balance of thrust through the nozzles must be maintained as it is imperative to aircraft operation. The scope of this project is to develop a new method of measurement for the hot nozzle with a working prototype that is generated at the end of the project.

System Overview

The current system consists of two Rear Hot Nozzles used by the AV-8B Harrier. These two nozzles assist the Harrier in its vertical takeoff and landing procedures by producing predetermined amounts of thrust. Ensuring these nozzles perform as expected is extremely important to the safety and mission of the Harrier pilots and the warfighter. The current overall system is shown in Figure 1.

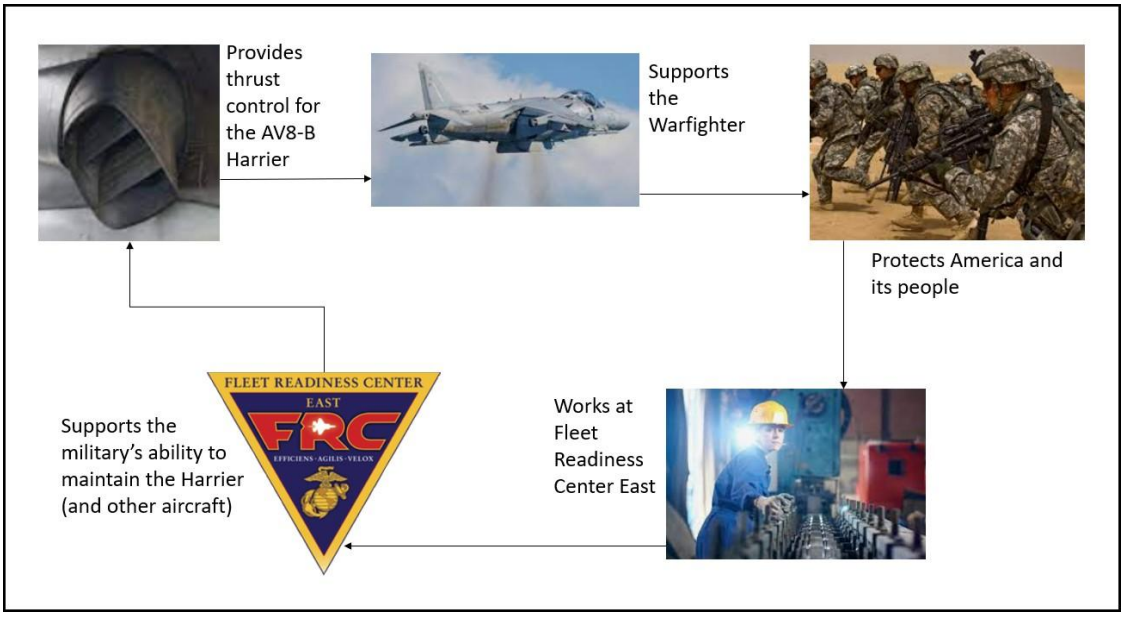


Figure 1: Overall System

The focus of this project is the measurement of the F-402 Rear Hot Nozzle. A full breakdown of the measurement system is shown in Figure 2 below.

Figure 2: Measurement Process

While this measurement system has supported the AV-8B for many years, Fleet Readiness Center East has proposed that under Capstone a new measurement system for the F-402 nozzle be produced. This system must last through the AV-8B Harrier sundown year of 2028.

Current System

Currently, the nozzle is taken off the engine during maintenance, reworked as needed, measured at the Navy Engine Airfoil Center (NEAC), the nozzle is installed on an engine, thrust tested in a test cell, and then the engine is returned to the aircraft.

The current maintenance process is outlined below. After the nozzle is removed from the Harrier, it is repaired by welding or cold working as needed. It is then mounted to the test equipment below in Figure 3. If there are any trimmers (vanes that can be mounted in the top section of the nozzle to decrease outlet area) in the nozzle, they are removed before the measurement process continues.

Figure 3: Support Equipment for the Nozzle Trace

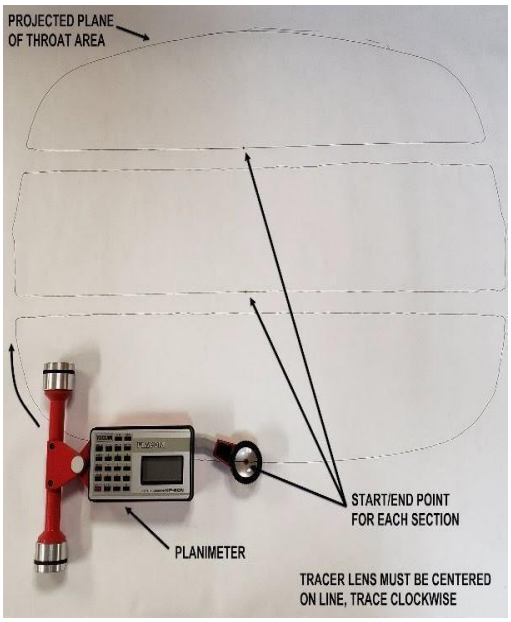
After the nozzle has been securely mounted to the stand in Figure 3, the interior of each section is traced using a stylus, Figure 4. The angle of the support equipment may be noted as a feature of interest. The interior vanes of the nozzle are angled at 22 degrees from the horizontal. To accommodate for this angle when tracing, the support equipment must also be angled so that the trace outlines the actual area and not a projected area.

Figure 4: Nozzle and Tracing Stylus

The stylus tip is placed 0.1 inches from the edge of each section at the center of the nozzle. The stylus is then moved around the entire section of the nozzle and a trace of each section is produced. After this, the area is then calculated from the trace via

a planimeter, Figure 5.

Figure 5: Nozzle Trace and Planimeter



Once the area is calculated for each section, the tracing and measuring process is repeated again. These two results are then averaged for each section and added together for the total area. The expected acceptable nozzle area range is 291 in^2 - 294 in^2. Once the nozzle has been measured, it is then installed on an engine and thrust tested, and after passing, the engine is returned to the aircraft.

Current System Deficiencies

As mentioned previously, although the current system has supported the Harrier, recent events have highlighted several system deficiencies. One such event involved personnel utilizing the nozzle as a 'footstool'. This caused the top section of the nozzle to be deformed and produce out of tolerance thrust values. More areas of concern are highlighted below.

As the stylus tip is moved around the nozzle, debris on the table has caused the stylus to shift, causing deviations in the trace and resulting measurement. The stylus head also has the potential to be angled. This means the stylus head is not perpendicular to the wall of the nozzle as it is moved around, giving a larger cross-sectional trace than the actual value. Weld seams within the nozzle also cause additional tracing issues. The team has traced one nozzle using the current method; during this process, as the stylus was routed along the nozzle it encountered the weld seams. This led to significant deviations in the cross-sectional area trace, and the stylus trace had to be repeated to obtain a fully developed outline. Per the technical engineering instruction

(TEI), the stylus head should be 0.1 inch from the edge of each section of the nozzle, but this standard is not always followed. When it is followed, establishing and maintaining the 0.1 inch depth is difficult and can lead to error in the trace. Additionally, the stylus is made of metal and the friction created between the metal stylus head and metal nozzle causes chattering in the trace. This in turn equates to error in the measurement trace and overall measurement.

The paper utilized for the trace is sometimes too small when it is cut. If the stylus and/or planimeter wheels fall off the paper onto the table, the drop will cause error in the trace and area. The planimeter itself is highly technical and difficult to learn. Keeping true to the trace for the entire area of the nozzle is extremely difficult due to human error. Currently, the time to trace one nozzle ranges from 1-1.5 hours. This, per the engineers on the project, is too long and should be reduced if possible.

Until recently, the stylus had no replacement parts and was roughly modified to continue operation. Support equipment has now been designed for the nozzle, but all spare parts must be designed or created by the depot meaning that additional workers and time must be spent in support of the stylus and nozzle.

The objective of this project is to develop a better methodology to do the nozzle measurement.

Expected Deliverables/Results:

The following deliverables are required:

1. Working prototype
2. Drawing Package (including Commercial Off The Shelf information)
3. Final Design Report
4. Maintenance and Operation Instructions
5. Risk Matrix
6. Parts List
7. Data Results From Initial Testing
8. Calibration Plan
9. Cost of Non-Recurring Engineering
10. Cost of System
11. Project Schedule

Disposition of Deliverables at the End of the Project:

Hardware developed is the property of the Industry Supporter. Expectation is to have the prototype available to FRC East CP personnel to transport back to Havelock NC after the end of the Expo.

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

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Specific Skills:

- For ME students, strong interest in Metrology. Would be a good project for a student planning to study Metrology in graduate school.
- Programming/Logic
- Electrical Circuit Design
- Machining
- CAD/3D Modelling
- Travel to NAVAIR in Cherry Point, NC will be required. ISL will reimburse travel expenses.
- Students and mentor must be US Citizens