RIF Final Report:
Experimental Facility Design for an Integrated Space Technology Research Laboratory at USC

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A. Background and Objectives

A vacuum chamber system is the basic experimental facility for space engineering and technology research. The Rapp Engineering Building currently houses three vacuum chamber systems (**Error! Reference source not found.**): a large-size chamber (CHAFF-IV), a medium-size chamber (CHAFF-I), and a small-size chamber newly installed in Prof. Wang's Lab in 2009. The CHAFF-IV chamber has a dimension of 3m in diameter and 6m in length, and is ranked among one of the largest vacuum chambers housed in an academic institution in the world. CHAFF-I is approximately 1.5m in diameter and 1.5m deep. The new, smaller chamber is 1m in diameter and 1.2m in length, and is suitable for small scale experiments. Currently, only the small chamber is operating at the designed condition. The medium-size CHAFF-I is not operational and the large-size CHAFF-IV is operating only under marginal conditions. This severally limits the scope of research activities that USC currently is able to propose to sponsors. The objectives of this RIF project are to develop a plan for repairing and upgrading the CHAFF-IV vacuum chamber in RRB and to develop a plan for establishing an integrated laboratory with unique experimental capabilities and "niche" research areas

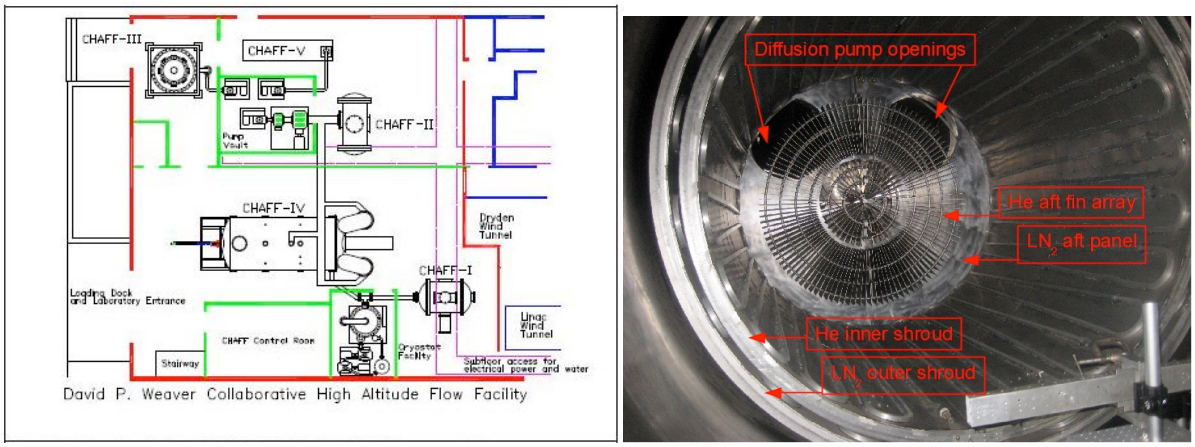

Figure 1: RRB Laboratory Floor Plan and CHAFF-IV Chamber Interior

B. Accomplishments

This RIF project has accomplished significantly more than the original objectives stated in the proposal. In addition to develop a repair plan, additional external funding was obtained so we were able to actually carry out many of the repair tasks. The following was accomplished during this RIF project:

1) developed a plan to repair and upgrade the CHAFF-IV facility
2) obtained funding for Phase-I CHAFF-IV repair ($47.5K)
3) completed Phase-I CHAFF-IV repair
4) obtained funding for research using the CHAFF-IV facility ($100K)

CHAFF-IV Repair and Upgrade Status: The CHAFF-IV chamber was originally designed to accommodate the testing of a variety of candidate electric and chemical thrusters for improved contamination and plume studies. Its cryogenic low-vacuum system was designed with a pumping capacity of $9x10^6$ L/s. An operational parameters verification test performed in 1999 indicated that the facility's ultimate pumping capacity could even surpass the predicted value of $9x10^6$ L/s. The facility is designed to be roughed with a mechanical pump (120 L/s) and a two-stage Roots Connersville blower pump (2000 L/s). The roughing system is also designed to back twin Zyrianka 900 diffusion pumps (25,000 L/s each for N_2) which are mounted at chamber back wall. The diffusion pumps initialize the facility for cryogenic pumping, provide supplemental pumping during cryogenic operation, and provide necessary pumping during cryogenic shutdown. The cryogenic system utilizes both LN_2 and He, and requires independent compressor/pumping mechanisms for each coolant. The LN_2 aft panel and outer shroud insulate the colder He aft fin array and inner shroud from the chamber walls. A LN_2 front panel and He front fin array also exist and would be utilized during optimal operation.

At the start of this project, the cryogenic system and one of the diffusion pumps were completely non-operational The other diffusion pump and the roughing pump train were also in need of overhaul. Additionally, the system water cooling loop was in disarray and the entire CHAFF-IV facility required significant control, measurement, and automation to prevent system damage. An independent LN_2 system (tank, pump, and transfer lines) must also be installed in order to shroud the cryogenic He system.

In the past year, a plan to repair and upgrade CHAFF-IV was developed. Several outside consultants and chamber vendors were also brought in to help with the design and/or to provide quotes for the repair. The repair/upgrade tasks were divided into 2 phases. The RIF fund and $47.5K obtained from AFRL were used to complete the Phase 1 tasks. Most of the Phase 1 repair work were performed by graduate and undergraduate students in house. As of June 2012, most of the phase 1 work has been accomplished, which include:
Roughing Pump Train overhauled successfully
Gate Valves repaired in-house
Green Diffusion Pump serviced and fully functional.
Water Cooling Loops fully refurbished and operational.
Automation of measurements & control of cooling loops and diffusion pump established.

C. Impacts and Future Tasks

The Phase 1 repair/upgrade of the CHAFF-IV facility has already shown an impact on astronautical engineering research at USC. The CHAFF-IV facility had been rarely used in sponsored research in recent years. With the completion of the Phase 1 work, we have already secured $100K in sponsored research from Air Force Research Lab utilizing the repaired CHAFF-IV. Various sponsors have also expressed an interest to us on research utilizing the completely upgraded CHAFF-IV. More over, an in-house vacuum chamber repair capability was also developed during the project. 6 graduate students and 4 undergraduate students had participated in the Phase 1 repair work. These students would play an important role in astronautical research at USC in the coming years.

The objective of the Phase 2 work is to upgrade the facility to the full designed capability. The accomplishment of the Phase 2 objective is dependent upon the installation of the **LN_2 Cooling System.** The LN_2 cooling system is in the cost assessment phase. A 1200 gallon LN_2 tank needs to be installed near RRB, and vacuum jacketed transfer lines are needed to route LN_2 to the chamber for experimental cooling. The installation of the LN_2 cooling system is a facility issue. A facility request has already been submitted to VSoE.