February 28, 2006

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Presenting:
David Omer, MAE Grad Student
Chimaera Project Overview

• History/Documentation
• Chimaera Rocket Design
• Results of Flight
• Conclusions and Future Plans
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David Omer, Chimaera Project Overview

Project History/Documentation

• Project History
  – “Unity IV” hybrid rocket project started in 1992
  – Successful launches in 1995 and 2003 at Utah Test and Training Range (west desert)
  – Switched to competition to increase frequency of launches, involve more schools
  – Launch site moved to Green River due to scheduling delays at UTTR
Project History/Documentation

• Objectives
  – Eventual goal: 100,000+ feet
  – Incremental approach with lower-altitude flights first
  – Basic airframe capable of 100,000 feet (propellant capacity)
  – Limited initial payloads, more sophisticated later
Project History/Documentation

• Documentation
  – Senior Design reports
  – Conference publications
  – Photos
  – Videos
  – Drawings
  – Archived on http://chimaera.usu.edu and ftp://chimaera.usu.edu
Launch Competition Plans

- First competition with BYU and University of Alabama Huntsville, 11-12 Nov 05
- Launch site near Green River UT, using White Sands Missile Range Green River Launch Site airspace and Bureau of Land Management land
- Portable launch rails and launch control bunker
- Criteria: Closest to 10,000 feet AGL, intact recovery, produce flight data, poster presentation, paper
- Second competition: Fall 2006
Chimaera Rocket Design
Motor / Nozzle

Motor
- Thin Aluminum Liner
- Welded Aluminum Flanges
- Carbon Fiber Filament Wrapped
- Removable Paper Phenolic Fuel Cartridge

Nozzle
- Silica Cloth/Phenolic Resin Ablative Liner
- Fiberglass Sealing and Load Bearing External
- Aluminum Mounting Ring
- Bell Profile to Reduce Divergent Length
- Optimum Altitude = 26,000 ft
- Area Ratio = 9.3
Chimaera Igniters

Igniter Properties

- Mounted in Injector Plate
- High Energy Output
- 12 second Burn time (30g fuel)

Igniter Composition

- 66% Ammonium Nitrate
- 22% Magnesium Powder
- 12% HTPB w/ 8:1 Curative
• Liquids and Gases
  – Liquid Nitrous Oxide (N₂O)
  – Pressurant - N₂
  – Pneumatic Actuators – CO₂

• Two Tanks
  – Carbon Fiber High Pressure tank
  – Aluminum K-bottle

• Operating Pressures
  – Oxidizer Tank Operating Pressure – 750 psi
  – Nitrogen Tank Operating Pressure – 2000 psi
Oxidizer

Pressurizing System

- High-Pressure Tank
- High-Pressure Regulator
- Check-valve
- Relief Valve
- Vent Valve
- Oxidizer Tank
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Oxidizer Valve System

- Solenoid Control Valve
- Main Oxidizer Valve
- CO₂ Actuation tank
- Motor
Airframe

- **Interfaces:**
  - **Motor Interface**
    - Motor brackets, thrust plate
  - **Oxidizer Interface**
    - Oxidizer brackets, Oxidizer plate
  - **Sectional Interface**
    - Sectional interface brackets, longerons
Recovery

• Primary Objectives
  – Recover the Rocket Intact (no damage)
  – Design for 10,000 ft (AGL) apogee
  – Keep a 1.5 mi footprint
  – No Pyrotechnics

• Secondary Objectives
  – Design for 100,000 ft (AGL) apogee
  – Keep a 5 mi footprint
1. Launch

2. Apogee

3. Release of nosecone by two microme cutters deploying drogue chute and nosecone chute

4. Nosecone descends at 19.9 ft/s to the ground

5. Main airframe descends at 21.9 ft/s to the ground

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Drift for 10,000 ft flight

This is drift for a 10,000 ft flight assuming a constant wind direction and constant wind speed of 7 mph.

Drift

\[ T_{\text{hang}1} := \frac{h_p - h_s}{v_1} \]

\[ T_{\text{hang}1} = 120.9 \text{ s} \]

\[ \text{Drift}_1 := T_{\text{hang}1} \cdot v_w \]

\[ \text{Drift}_1 = 1.2 \times 10^3 \text{ ft} \]

\[ T_{\text{hang}2b} := \frac{h_s}{v_{b2}} \]

\[ T_{\text{hang}2b} = 228.2 \text{ s} \]

\[ \text{Drift}_2b := T_{\text{hang}2b} \cdot v_w \]

\[ \text{Drift}_2b = 2.3 \times 10^3 \text{ ft} \]

\[ T_{\text{hang}2t} := \frac{h_s}{v_{t2}} \]

\[ T_{\text{hang}2t} = 401.1 \text{ s} \]

\[ \text{Drift}_2t := T_{\text{hang}2t} \cdot v_w \]

\[ \text{Drift}_2t = 4.1 \times 10^3 \text{ ft} \]

\[ \text{Drift}_{\text{total top}} := \text{Drift}_1 + \text{Drift}_2t \]

\[ \text{Drift}_{\text{total top}} = 1 \text{ mi} \]

\[ \text{Drift}_{\text{total bot}} := \text{Drift}_1 + \text{Drift}_2b \]

\[ \text{Drift}_{\text{total bot}} = 0.7 \text{ mi} \]

Nose drift

\[ t_{\text{hang}n} := \frac{h_p}{v_n} \]

\[ t_{\text{hang}n} = 500.3 \text{ s} \]

\[ \text{drift}_n := t_{\text{hang}n} \cdot v_w \]

\[ \text{drift}_n = 1 \text{ mi} \]
Communications/Interface

- Ham Radio – DTMF audio tones
- Frequency – 146.430 MHz

- Commands:
  - *#1 – Vent Close
  - *#2 – Vent Open
  - *#3 – Ox Valve Close
  - *#4 – Ox Valve Open
  - *#5 – Igniter On
  - *#6 – Arm
  - *#7 – Safe
  - *#8...A – Launch Sequence
  - *#9 – In Flight Abort
  - *01 – Deploy Drogue Chute
  - *02 – Deploy Main Chute
Data Acquisition

- RDAS – Rocket Data Acquisition System
  - Internal Sensors
    - Single Z-Axis accelerometer
    - Atmospheric Pressure
  - External sensors
    - Nitrogen Tank Pressure
    - NOX Tank Pressure
    - Injector Pressure
    - Motor Pressure
    - Z-axis Gyroscope
    - plus one more for expansion
- Data Capacity
  - 8 min at 50 Hz with 6 external sensors
Video Downlink

- 3G Hi-Power BoosterVision Transmitter/Receiver Kit From BoosterWorks.com
- Dimensions:
  - Transmitter 4” x 2.5” x 1.75”
  - Camera 25mm x 25mm square
- Range
  - 4,200 feet in open air.
  - 15,000 feet with booster antenna
- Full Color
- Mono sound
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Chimaera launch, Jan. 5, 2006
• 1st place in Experimental Sounding Rocket Association (ESRA) competition against University of Alabama Huntsville

• Approximately 5740 ft AGL.

Data collected included
• Axial acceleration
• Range data
• Injector Pressure
• Chamber Pressure
• Tank Pressures
Comparison of data collected to simulation allows us to back out estimates of the motor thrust, overall drag, and specific impulse of the motor.
The following performance values were estimated through simulation:

- $I_{sp} \approx 200$ seconds
- $Thrust \approx 1800$ lbf.
Summary of Performance

- Reached ~ 5740 ft AGL
- Recovered data, nosecone, and some peripheral components
- Thrust loss due to altitude and injector flow rate

- Only source of failure was Recovery System
- Recovery system failed to detect apogee and/or signal parachute deployment upon detection
- Exact cause of system failure unknown due to impact damage
Future Project Plans

New iteration of Chimaera under development, building upon past successes and lessons learned.

Future work aims to keep with the original project goals, i.e. achieve successively higher altitude launches until reaching sounding-rocket range (150,000-250,000 ft).

Possible research areas:
• Flight termination systems
• Efficient hybrid motors (new fuels or oxidizers)
• Nozzle development
• Injector development
Questions?

Thank you