Flight Dynamics Study with the XCOR Lynx using the Suborbital Space Flight Simulator and Mission Control Center

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Abstract

This study was conducted to better understand the XCOR Lynx vehicle. Because the Lynx development was halted, the best knowledge of vehicle dynamics can only be found through simulator flights. X-Plane 10 was chosen for its robust applications and accurate portrayal of dynamics on a vehicle in flight. The Suborbital Space Flight Simulator (SSFS) and Mission Control Center (MCC) were brought to the Applied Aviation Sciences department in fall 2015. This academic and research tool is a department asset capable of providing multiple fields of data about suborbital simulated flights. This tool will allow us to assess different aspects of a suborbital flight dynamics and a trajectory map was created. It was found that the XCOR Lynx is an unstable platform but has good glide capabilities. This information is of use for pilots who may someday fly the XCOR Lynx as well as air traffic controllers who may have Lynx operations at their airports.

Introduction

The SSFS is able to simulate suborbital flights and diverse mission profiles. The simulator is linked to the adjacent room (MCC) where live tracking is provided to several consoles. Relevant data from X-Plane 10 is also recorded in a notepad .txt document. This research is to aid in the understanding of multiple aspects of suborbital flight as well as the XCOR Lynx. Though the Lynx development is currently suspended, this information is useful to have in case the vehicle continues development at a later date. The Figure 1 images below depict the XCOR Lynx in different phases of flight, described in the Methodology.

a: Takeoff b: Pitch-up c: Nose down d: Glide

Figure 1: The XCOR Lynx suborbital flight during various phases

Research Objectives

1. Learn about the flight characteristics of the XCOR Lynx.
2. Determine nominal trajectory.
3. Determine best glide and max glide range.
4. Determine feasibility of a space traffic corridor.

Methodology

Eight flights were flown in the SSFS from Daytona Beach International Airport (KDAB). The flights were comprised of seven phases:

1. Takeoff and establish a trajectory of 45 degrees vertical to 20,000 feet. (Fig. 1a)
2. Rapid pitch-up to about 80 degrees vertical, no bank angle. (Fig. 1b)
3. Hold pitch attitude to main engine cutoff at ~190k feet.
4. Follow ballistic trajectory through apogee and begin reentry at 250k feet.
5. Hold 65 degrees nose down and maintain stable reentry with reentry brakes deployed. (Fig. 1c)
6. At 100k feet, start pitch-up maneuver and retract reentry brakes.
7. Turn back and glide to land at KDAB. (Fig. 1d)

The flight data was collected from the data.txt file and processed in MATLAB.

Results

The data [ref. 1] provided was then graphed into two areas of focus. The SSFS Flight Corridors for the Lynx shown in Figure 2 gives us a X, Y, Z graph of the Lynx's flight profile. This is used for determine the 3D footprint of a typical flight out of KDAB. This tells us how local air traffic would predictably be impacted and to what extent.

Data was also graphed in regards to angle of attack versus time and distance in two different graphs. This gives a visual representation of the flight dynamic in that region of flight. While X-Plane 10 can depict lift at a specific area of the aircraft, the mean angle of attack was chosen instead due to the fact that the lift representation would not be viable in the vacuum period of the flight. Results show angles of attack near critical during the reentry period shown in Figure 3. Very rapid oscillations are also shown during that time in Figure 4, emphasizing the lack of stability of the space vehicle design.

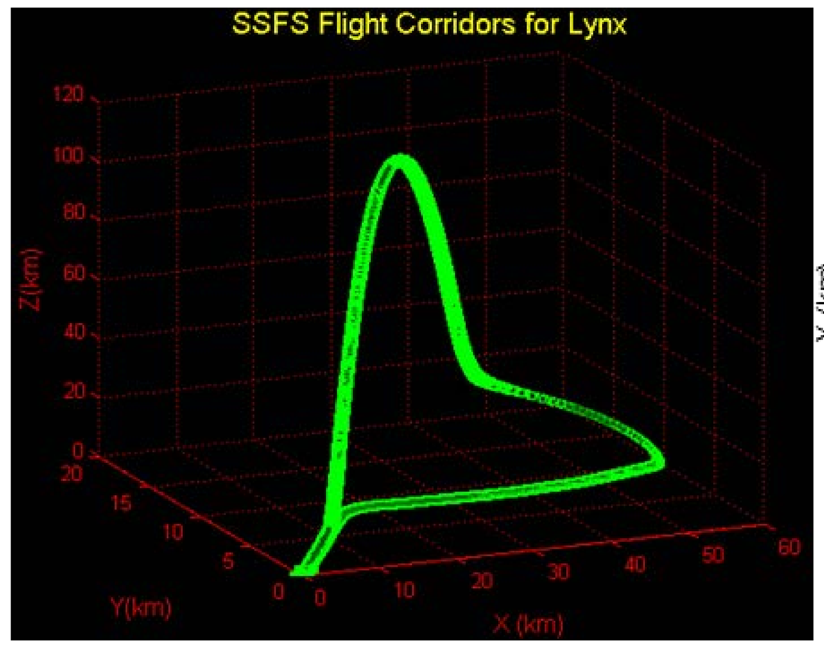

Figure 2: XCOR Lynx 3D transition corridor.

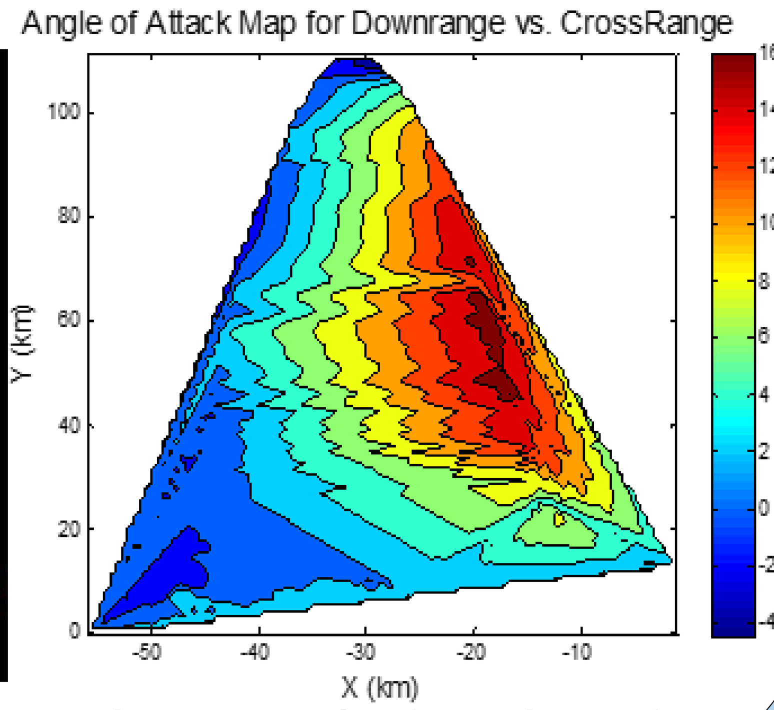

Figure 3: Angle of Attack map for X, and Y position

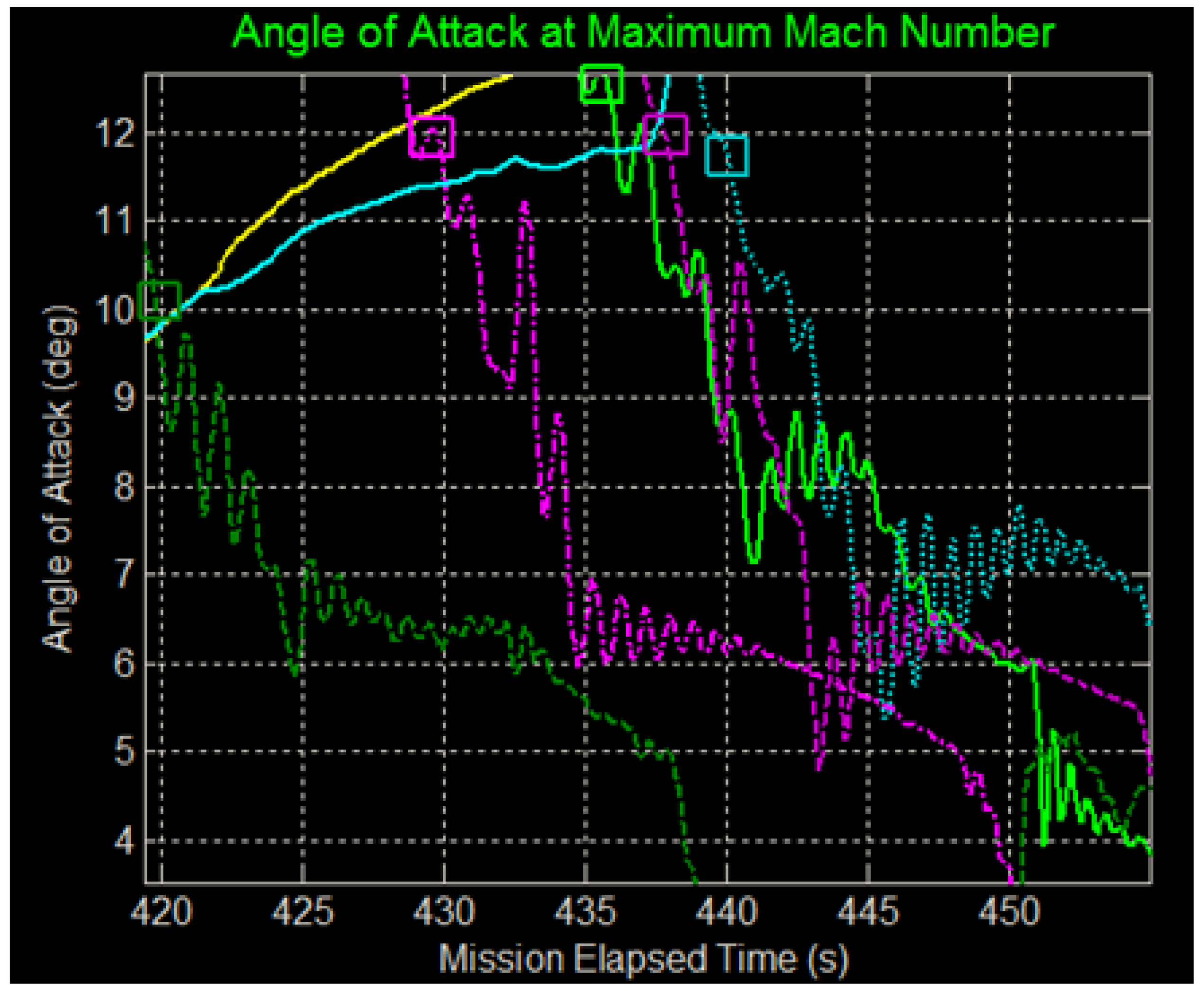

Figure 4: Angle of Attack versus time during reentry, before glide segment.

Conclusions and Recommendations

XCOR Lynx has a workable flight model and good glide range for the design of the spacecraft. However, it is an unstable design. If the pilot does not perform a proper reentry and maintain control, the Lynx will become uncontrollable. Stall characteristics in atmosphere is also an issue; as it has a rear heavy center of gravity. When stalled at low airspeeds, the spacecraft has difficulty pitching down to break the stall, and must use its reaction control thrusters (RCS) to force the nose down.

In the way of trajectory and airspace, the spacecraft accelerates through class Alpha airspace quickly enough to not be a concern for most air traffic, provided advanced notice to the center that controls flights in that area. On the return, the spacecraft is a glider. It thus has right of way over other aircraft except for emergencies. Traffic should deconflict as such.

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References

[1] Llanos, P., Nguyen, C. Williams, D. et al. (2017). *Space Operations in the Suborbital Space Flight Simulator and Mission Control Center: Lessons Learned with XCOR Lynx.* To be submitted to the JAAER. Embry-Riddle Aeronautical University, Daytona Beach, FL.