Nomad Flight Performance Expansion

1 September 2019

Version 1.2

XYZ Aerospace

645 Colonel Glenn Blvd

Dayton, Ohio

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Contents

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1. Introduction

The first Nomad design phase focused on updating the legacy vehicle configuration to meet the OTSS-E performance requirements, specifically in the areas of GPS jam resistance and control link flooding resiliency. In addition, the legacy Chinese made flight controller was replaced with a US made form-fit-function replacement. Finally, navigation performance issues found during initial testing were addressed with an updated GPS/INS system. Testing was conducted over 5 days (10 August through 14 August 2019) in Dayton, Ohio.

2. Navigation

2.1. Test 04-01

Test 04-01 re-tested the basic navigation accuracy of the system in the initial Nomad-01 configuration.

TEST 04-01 METADATA

DATE	10 August 2019
LOCATION	Dayton, Ohio
ALTITUDE	900 ft MSL
CONFIGURATION	Nomad-01-01
WEIGHT	27.2 lbs
XCG	0.78 in
YCG	0.12 in
ZCG	1.21 in

2.1.1. Stationary Error

During testing, the Nomad-01 navigation system showed improved performance. Testing was conducted by holding the vehicle steady at a constant altitude (300 ft AGL).

TEST 04-01-01

TIME	1400L
TEMPERATURE	85 deg F
LATITUDE ERROR	9.5 ft
LONGITUDE ERROR	9.5 ft
ALTITUDE ERROR	9.8 ft
ABSOLUTE VELOCITY	0.1 ft/s

2.1.2. Moving Error

Test point 04-01-02 also showed improved performance. Testing was conducted by moving at a constant velocity (2.4 ft/s) at a constant altitude (300 ft AGL).

TEST 04-01-02

TIME	1500L
TEMPERATURE	75 deg F

LATITUDE ERROR	5.1 ft
LONGITUDE ERROR	5.0 ft
ALTITUDE ERROR	7.2 ft
ABSOLUTE VELOCITY	2.4 ft/s

2.2. Test 04-02

Test 04-02 tested the resistance to GPS jamming of the updated navigation system. To accomplish the test, a software test feature was enabled to ignore GPS data, resulting in relying only on the inertial data. This feature was enabled once the vehicle reached 300 ft AGL, simulating GPS jamming after mission start.

TEST 04-02 METADATA	
DATE	10 August 2019
LOCATION	Dayton, Ohio
ALTITUDE	900 ft MSL
CONFIGURATION	Nomad-01-01
WEIGHT	27.2 lbs
XCG	0.78 in
YCG	0.12 in
ZCG	1.21 in

Test 04-02 showed significantly degraded GPS performance during operations. Stationary performance was the most impacted, because the inertial system loses accuracy without movement to automatically calibrate the accelerometers. Without GPS, accuracy degraded rapidly over time; testing demonstrated over 100 feet of error after 2 minutes of operation. When moving was continuous from a known reference point, the inertial system was able to maintain +/- 2 feet for up to 5 minutes of continuous motion. However, as soon as the system stopped, the error rose sharply.

2.3. Test 04-03

2.3.1. Updated FCS Regression Testing

An important modification to Nomad vice Wanderer was the replacement of the Chinese made flight controller with a US made replacement. Test 04-03 replicated multiple test points from previous tests, including flight qualities and flight performance. Testing showed that the updated FCS behaved identical to the legacy system.

Experiment Note: Consider this description to be valid. The FCS capability was implemented exactly as capable as the legacy variant.

3. Control Link

3.1. Test 05-01

Test 05-01 demonstrated the resilience of the control link to flooding. The System Requirements Document defined flooding as 10 or greater messages per second. To quantify the effects of control link flooding, XYZ chose to conduct the tests at the nominal rate (1 message per second), and at 5, 8 and 10 messages per second. To achieve this, the ground station was modified to send the true message at 1 hz, and then add in extra messages spaced evenly between messages. These extra messages contained garbage values.

TEST 05-01 METADATA	
DATE	12 August 2019
LOCATION	Dayton, Ohio
ALTITUDE	900 ft MSL
CONFIGURATION	Nomad-01-01
WEIGHT	27.2 lbs
XCG	0.78 in
YCG	0.12 in
ZCG	1.21 in

Test point 05-01-01 showed at 5 mps, performance was not degraded in any performance characteristic. At 8 mps, some flight characteristics began to have random degraded behavior. For example, control input would be dropped occasionally. The message dropping occurred infrequently enough that the system was easily able to operate when the next message successfully came through. Users reported that they were not able to detect dropouts; rather, the drops were detected in post flight analysis. At 10 mps, the drops were sufficiently frequent that the users reported degraded operational performance. As multiple messages were failed in a row, latency built up in the system such that users were increasing control input to account for failed actions. Because it was not consistent, users were not easily able to adjust behavior to match latency.

TEST ID	
TIME	1200L
NOMINAL (1 MPS)	Pass
5 MPS	Pass
8 MPS	Degraded
10 MPS	Fail

Post flight analysis showed that the system was the control authentication system successfully prevented the flight control system from accepting erroneous messages. Analysis is ongoing to determine the cause and develop a fix.