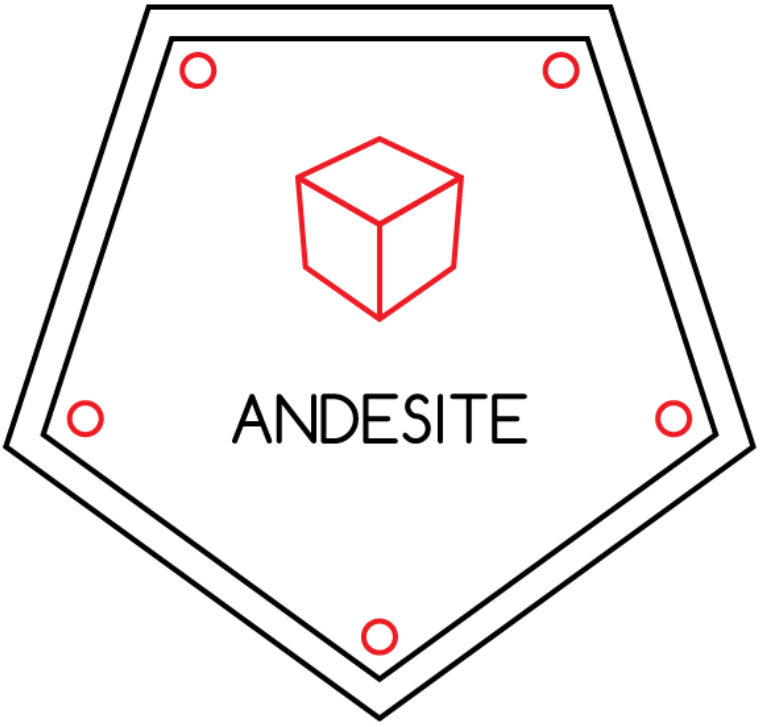
# Node Orbital Dynamics Considerations

## ANDESITE PROGRAM




Boston University
8 St Mary's St
Boston, MA 02215

## CHANGE LOG

| Revision | Date Submitted | Authors | Description | Notes |
|---|---|---|---|---|
| v1 | 6.28.17 | JBP | Orbit for FCC | |
| v2 | 4.2.18 | JBP | Update for FCC License | |

Table 1: Change Log

## RELEASE APPROVAL

Prepared By:

| | |
|---|---|
| Maria Kromis, Boston University | Date |
| David Einhorn, Boston University | Date |
| Osi Van Dessel, Boston University | Date |
| Hannah Levin, Boston University | Date |
| J. Brent Parham, Boston University | Date |

Approved By:

| | |
|---|---|
| Joshua Semeter, PI, Boston University | Date |
| J. Brent Parham, Project Manager, Boston University | Date |
| Osi Van Dessel, Project Engineer, Boston University | Date |

This document is part of the ANDESITE team documentation, and its purpose is to independently serve as a comprehensive guide to understanding, operating and rebuilding the subsystem described within. This document is the authoritative resource for this subsystem and supersedes all other previously written documentation including presentation slides, previously written Design Documents, and individually recorded notebook entries.

# 1. Summary

This analysis shows that Node-to-Node, and Node-to-Mule, collisions are highly unlikely to occur.

The Nodes are ejected in pairs, in opposite directions orthogonal to the velocity vector. Ejection imparts a velocity of 2 to 3 meters / second to the node, relative to the Mule. Consequently, the velocity of the two nodes relative to one another, will be 4 to 6 meters per second, away from one another. In order for one node in a pair to achieve conjunction with another, the relative velocity would need to change by 4 to 6 meters per second, there is no mechanism by which a delta-v of this magnitude could occur.

The ratio of drag force to mass will be significantly higher for Sensor Nodes than for the Mule, so the Sensor Nodes will continually move away from the Mule. Therefore, there is no scenario in which an ejected node can have a conjunction with the Mule.

Deployment of each pair is commanded from Mission Control. The plan is to space pair deployment so that the previously ejected pair would have drifted away about 5 km. The deployment decision is ultimately made after observing the dynamics of the previously ejected pair.

# 2. Orbital Analysis Methodology

To calculate the lifetime and formation dynamics we used a high fidelity orbital propagator as described in Table 1. This propagator exceeds those used in the standard SGP4 used by NORAD, so that we can accurately characterize the relatively close proximity of the swarm in its early stages of deployment.

*Table 1: Parameters for orbital simulation*

| | |
|---|---|
| **Gravity Model** | EGM2008 70x70 degree/order |
| **Atmosphere** | NRLMSISE-00 |
| **Celestial Bodies** | Sun, Moon and all Planets |
| **Solar Radiation Model** | Umbra/Penumbra |
| **Other Effects** | Relativistic Effects<br>Earth Albedo<br>Earth Solid Tides |

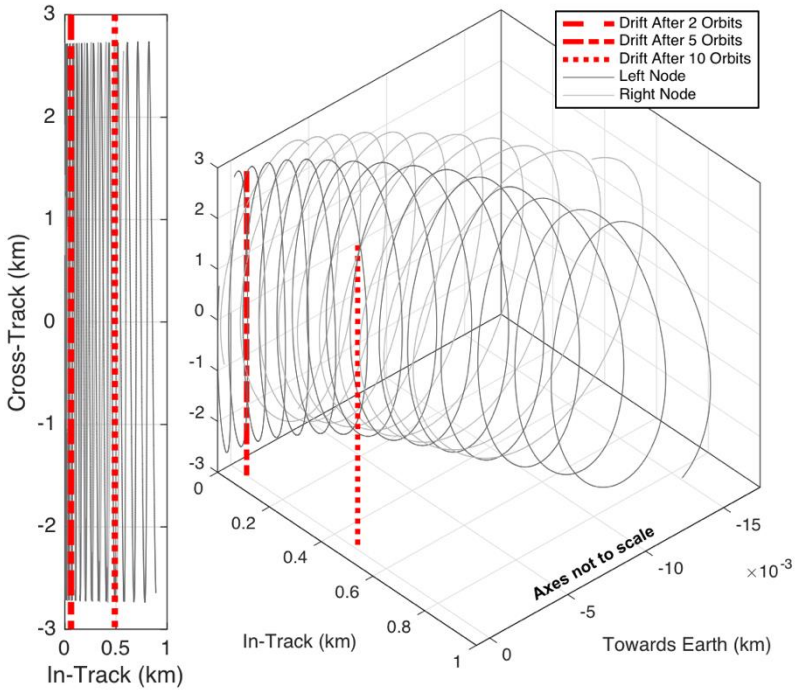



*Figure 1: ANDESITE Formation showing differential drift between nodes as seen in the main 6U Mule Coordinate Frame*

## 3. Node Orbital Lifetime and Collision Considerations

We expect all nodes will have reentered within a year of their deployment from the mule after deployment below the ISS.

To consider probability of collision also in supplement to the NASA provided ODAR, Figure 1 shows the relative distance between the mule and nodes along with inter-node minimum approach distances. The nodes drift along the orbital track due to their differing ballistic parameters and do not cross each other's trajectories due to the asymmetry of the gravitational perturbations that each encounter. Within a few orbits the nodes will not come within 100 m of each other, with relative speeds of < 2 m/s. While they drift away from the main 6U spacecraft they will never deviate from the main orbital plane by more than 2.5 km with all the associated formation drift occurring in the mean anomaly or velocity direction. Therefore, their chance of collision with other satellites individually remains the less than the chance calculated by the NASA ODAR for the 6U mule due to their smaller size. These separation distances would increase faster if the nodes are deployed at lower altitudes.

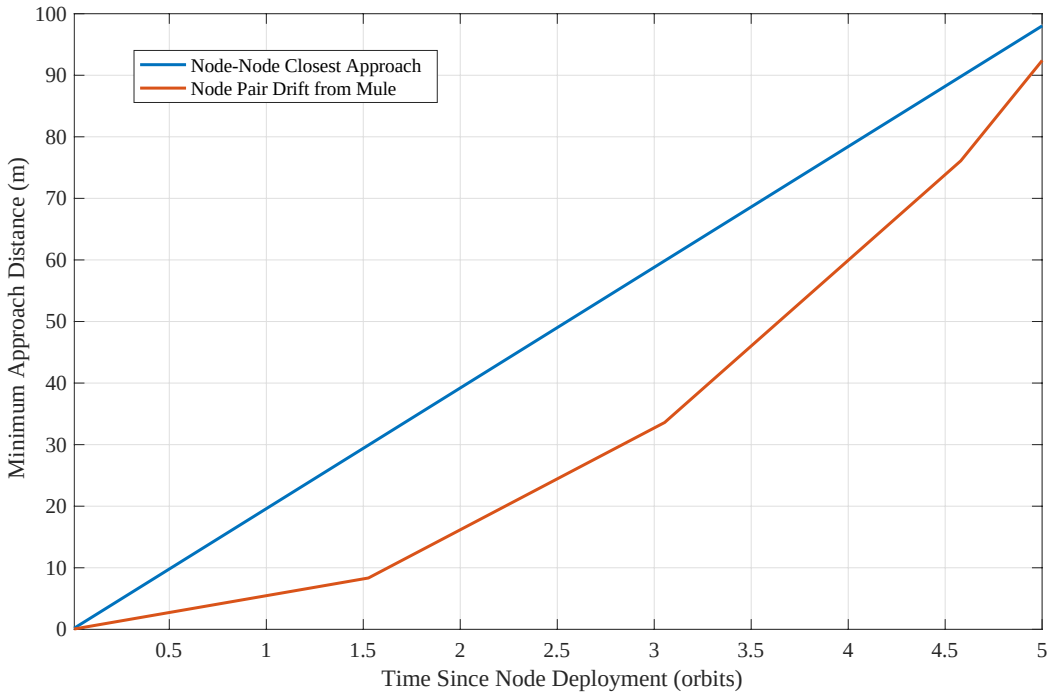



*Figure 1: Minimum separation distances between nodes and mule and each node of a pair*