ICCSwarm: Appendix

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A FULL SIMULATION RESULTS

Table 1 shows the full simulation results on the full-scale orbits. These results show the volumes of data captured by six small data collecting satellites and returned to a single carrier satellite. Data was captured at a 20 second interval.

Table 1. Full Simulation Results

		AODV		Single-Hop	
Sim. Duration (*hr*)	Data Collected (*MB*)	Avg. Data Ret. (*MB*)	Std. Dev.	Avg. Data Ret. (*MB*)	Std Dev
24	38.87	30.88	2.68	13.43	5.16
27	43.73	39.01	0.47	12.54	5.70
30	48.59	45.69	1.05	12.77	8.69
33	53.45	50.30	0.97	8.93	3.27
36	58.31	47.78	3.41	20.95	6.73
39	63.17	55.80	0.50	20.42	6.13
42	68.03	58.60	4.56	21.01	3.88
45	72.89	65.39	4.75	17.64	3.69
48	77.75	61.50	4.85	13.69	6.62

B ORBIT TRANSFORMATION

To create replica orbits that can be flown by UAVs, we reduce the size of the orbits and transform them from the asteroid-centered frame of reference (as shown in Fig. 2 (a)) to the carrier-centered frame of reference, as seen in Fig. 2 (b).

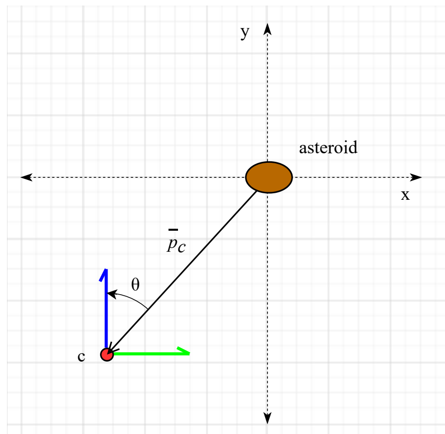


Fig. 1. Demonstration of how to find θ. The read dot is the carrier satellite and the brown object at the origin is the asteroid.

Each satellite's orbit is given as a set of x, y, z coordinates at discrete time steps. At any given time step, let $\vec{p}_c$ be the coordinate vector for the carrier's position and $\vec{p}_a$ and $\vec{p}_s$ be the coordinate position vectors for the asteroid and some data collecting satellite, respectively. By definition, the asteroid sits at the origin with the carrier satellite orbiting the asteroid on the z-plane. Let θ be the angle from a unit vector at the carrier pointing in the y direction to the origin, where the asteroid sits. To transform the coordinates of the asteroid and the small satellite to the carrier's frame of reference, where the asteroid sits directly above the carrier along the y-axis, we first do a linear translation to move $\vec{p}_c$, $\vec{p}_a$ and $\vec{p}_s$ to the origin of the carrier's frame of reference then do a 3-dimensional rotation around the z-axis. Let $\vec{t}$ be the translation to move the origin, which is defined as

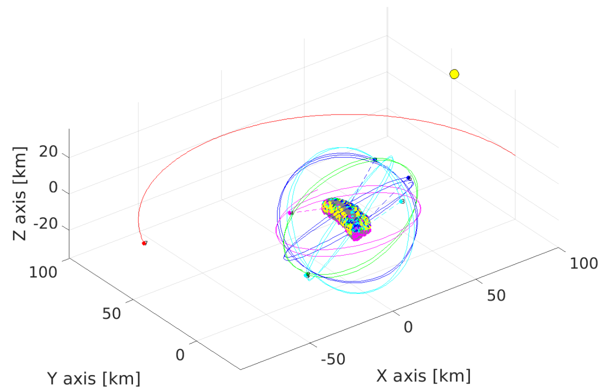
$$\vec{t} = \vec{p}_a - \vec{p}_c. \tag{1}$$

Let $\mathbf{A}$ be the rotation matrix where

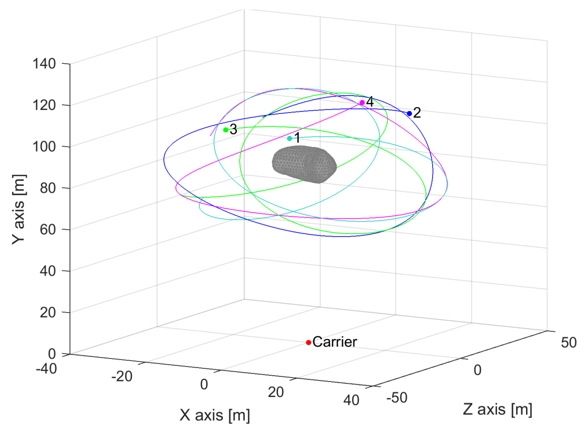
$$\mathbf{A} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1. \end{bmatrix} \tag{2}$$

To transform the asteroids position to the carrier's frame of reference, we set the asteroids position to

$$\vec{p}_a = \mathbf{A}(\vec{p}_a + \vec{t}) \tag{3}$$



(a) Output of orbit generator



(b) Transformed versions of the orbits.

Fig. 2. Example output from orbit generator. In (a), the larger, red orbit is the carrier satellite while the smaller, multi-colored orbits are the small satellites. Plot (b) shows the transformed versions of the orbits in (b), scaled down to a size that UAVs can travel.

We repeat this operation for the asteroid and every satellite's position at every time step in the orbit. To scale these transformed orbits down to a size that can be flow by UAVs on Earth, we found that a scaling factor of 7.9414×10^{-4} keeps the orbits below 121 m, the max allowable altitude for UAVs in the US.

C FIELD TEST RESULTS

Table 2 shows the results from both the testbed and simulation on the two orbit sets selected for field testing. Both the simulation and field-test were conducted using three small data collecting satellites and one carrier satellite. All data captured and returned is in *MB*. In the simulation, data was captured at a 20 second interval and on the physical testbed it was captured at a 50 millisecond interval. The simulations were on the original, full-size orbits while the testbed data was on the scaled-down orbits.

Table 2. Results on Field-Test Orbits

	Orbit 1						Orbit 2					
	AODV			Single-Hop			AODV			Single-Hop		
	Cap.	Ret.	% Ret.	Cap.	Ret.	% Ret.	Cap.	Ret.	% Ret.	Cap.	Ret.	% Ret.
Testbed	26.66	21.08	79.08	26.59	0.19	0.73	26.61	11.22	42.17	26.59	0	0
Sim. (116 dB)	29.16	21.44	73.55	29.16	3.56	12.21	29.16	13.38	45.88	29.16	4.67	16.03
Sim. (118 dB)	29.16	24.59	84.32	29.16	8.90	30.53	29.16	24.57	84.26	29.16	10.05	34.48