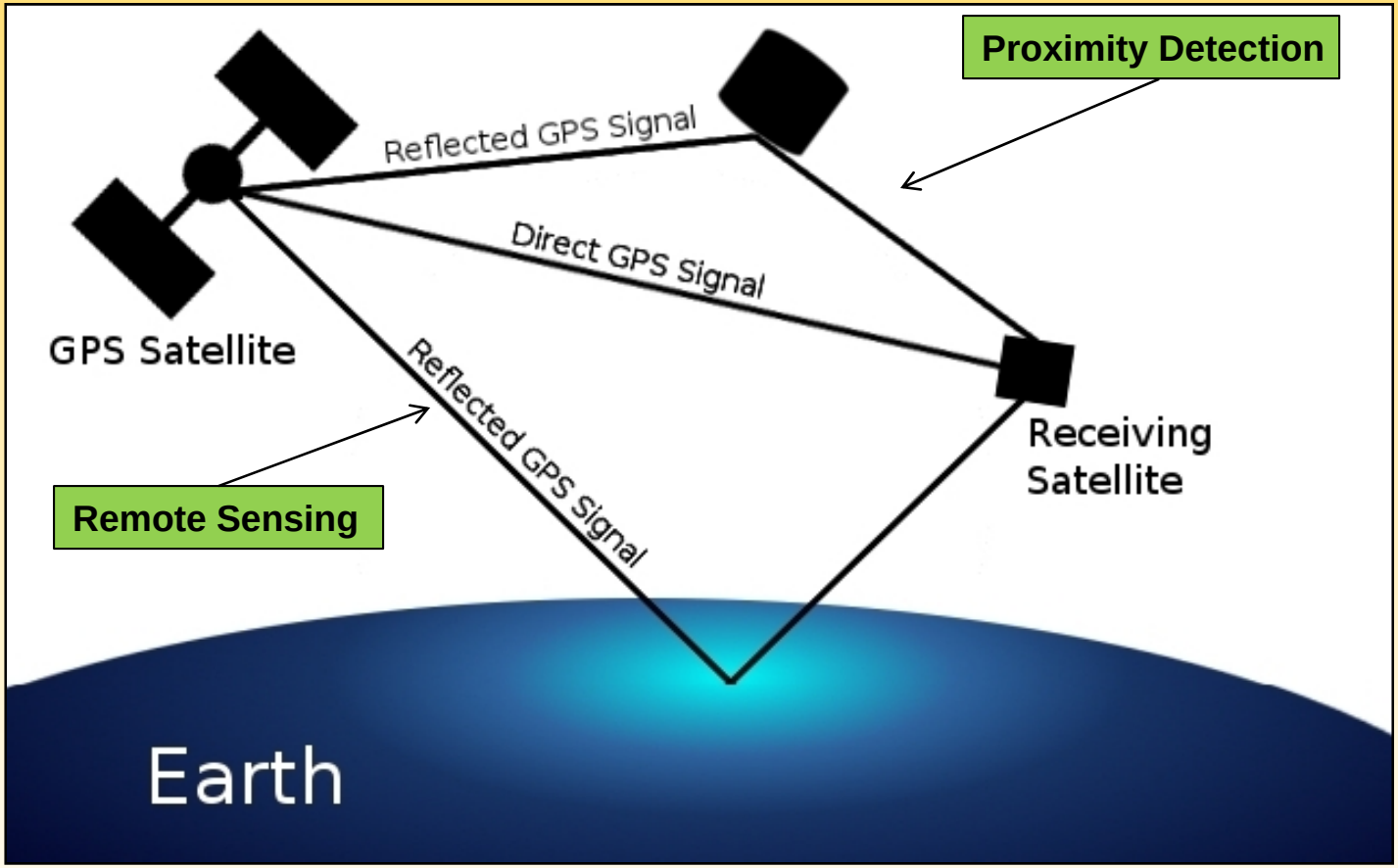
A GPS Bistatic Radar for Small Satellite Applications

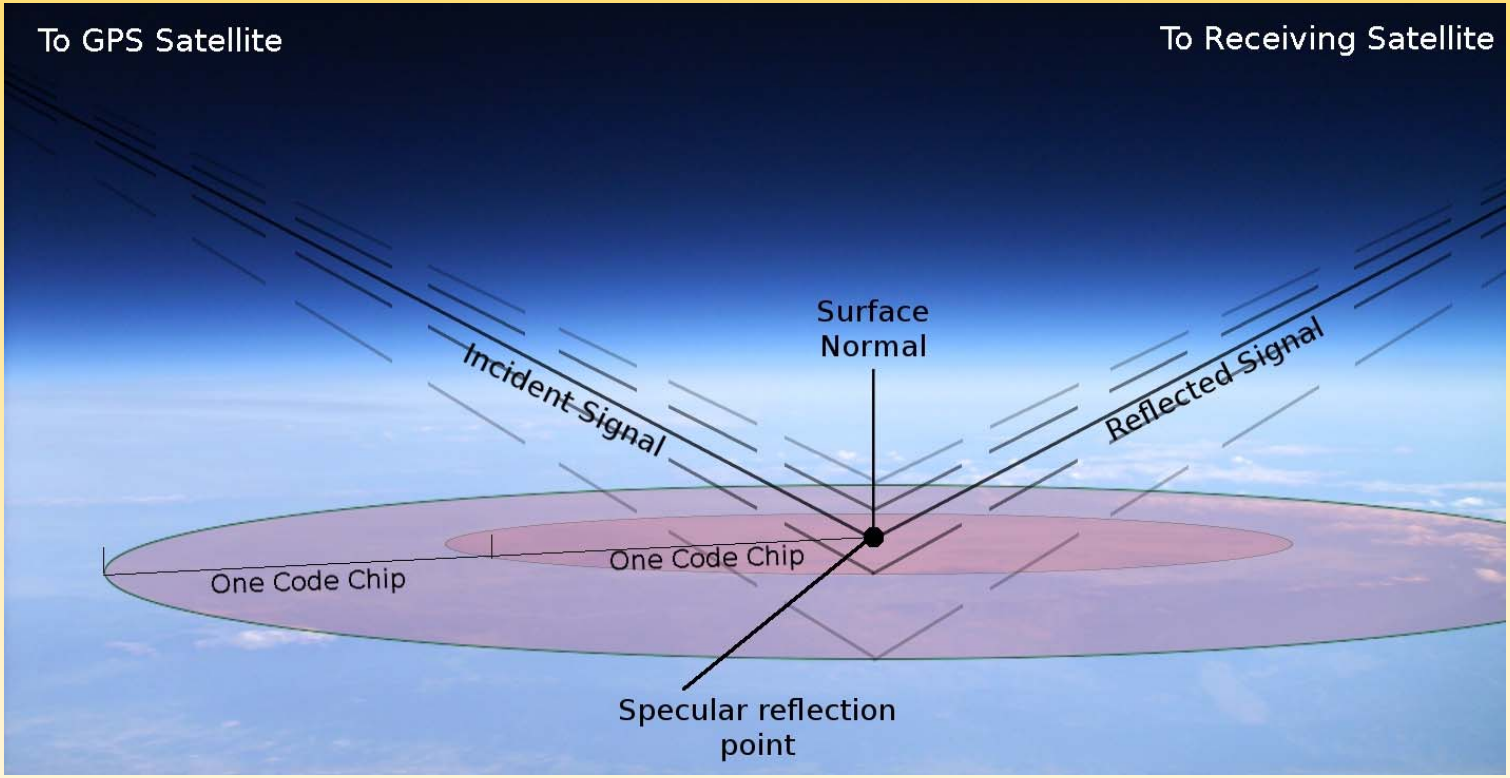
Jim Pogemiller
jimp@aem.umn.edu

UNIVERSITY OF MINNESOTA
Driven to Discover℠

What is GPS Bistatic Radar (GPS BR)?

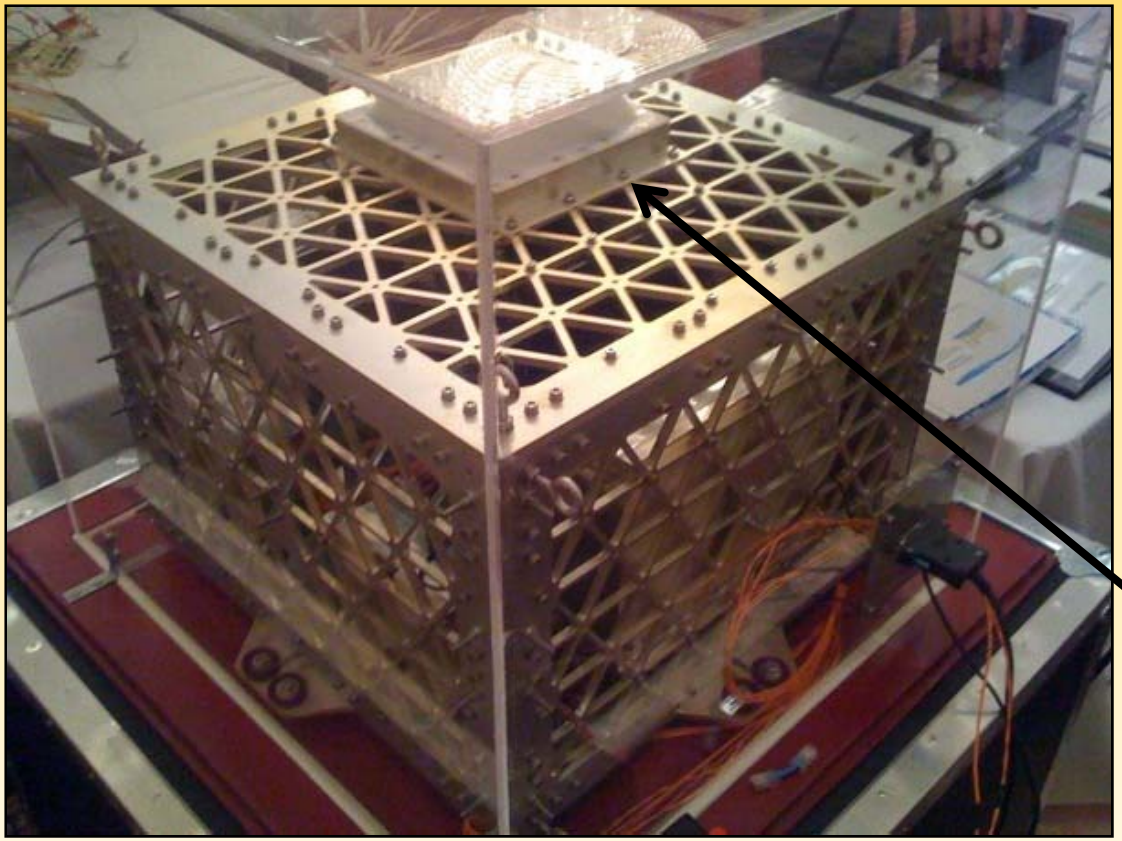


GPS BR Basics



One Code Chip (about 293 m) is the width of one bit of the GPS C/A Code.

GPS BR on a Nanosatellite



Goldeneye:
- Non-launched
- AFRL Sponsored
- University Nanosat program

High gain, dual polarity antenna

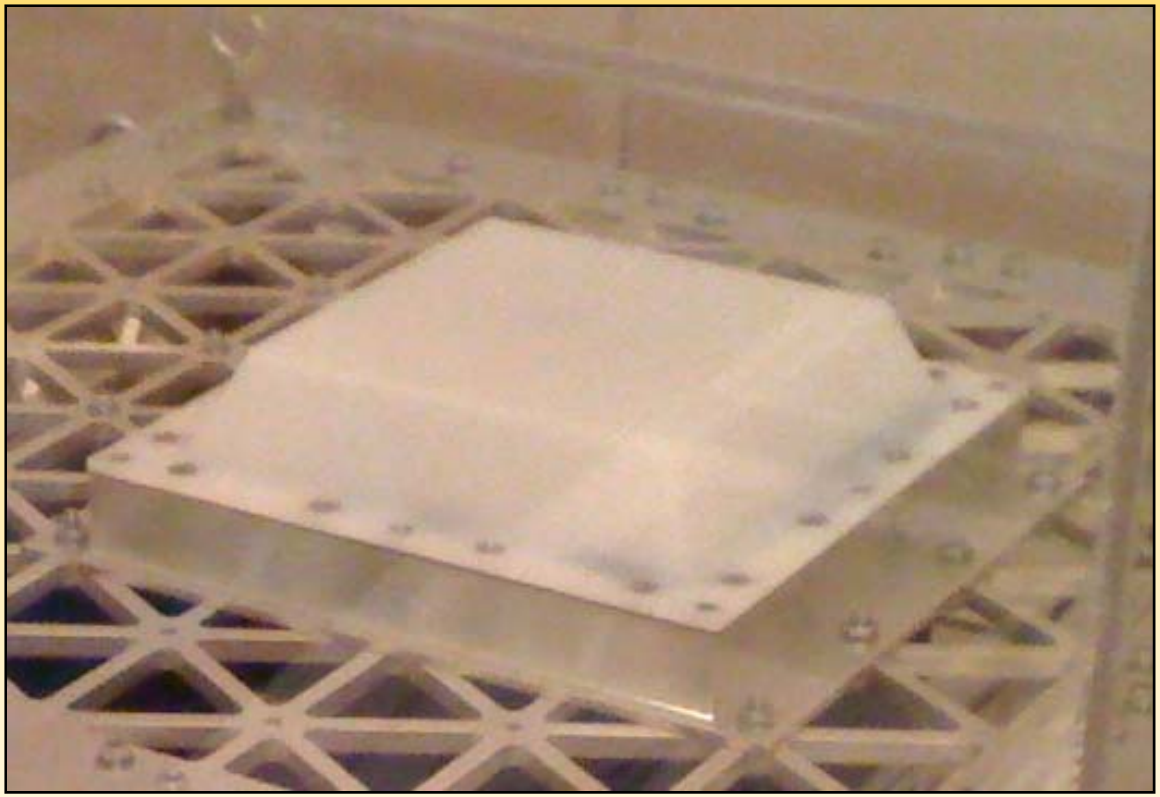
GPS Signal Power

GPS L1 frequency = 1.575 GHz
Right Hand Circularly Polarized (RHCP)
Power = 27 W transmitted -> -160 dBW

Reflection/Scattering
Absorption/Transmission
Mismatched Polarities

1.575 GHz + Doppler Shift
Left Hand Circularly Polarized (LHCP)
Power < -160 dbW

Power Loss Compensation



Dual Polarity:
RHCP
LHCP

High Gain:
8.5 dBiC

GPS BR Observables

Bistatic Radar Equation:

$$P_R = \frac{P_T G_T G_R L_a \lambda^2 \sigma}{(4\pi)^3 R_T^{\,2} R_R^{\,2}}$$

Parameter	Value
P_T	27 W
G_T	12.9 dB
λ	0.1903 m
R_T	~20,000 km

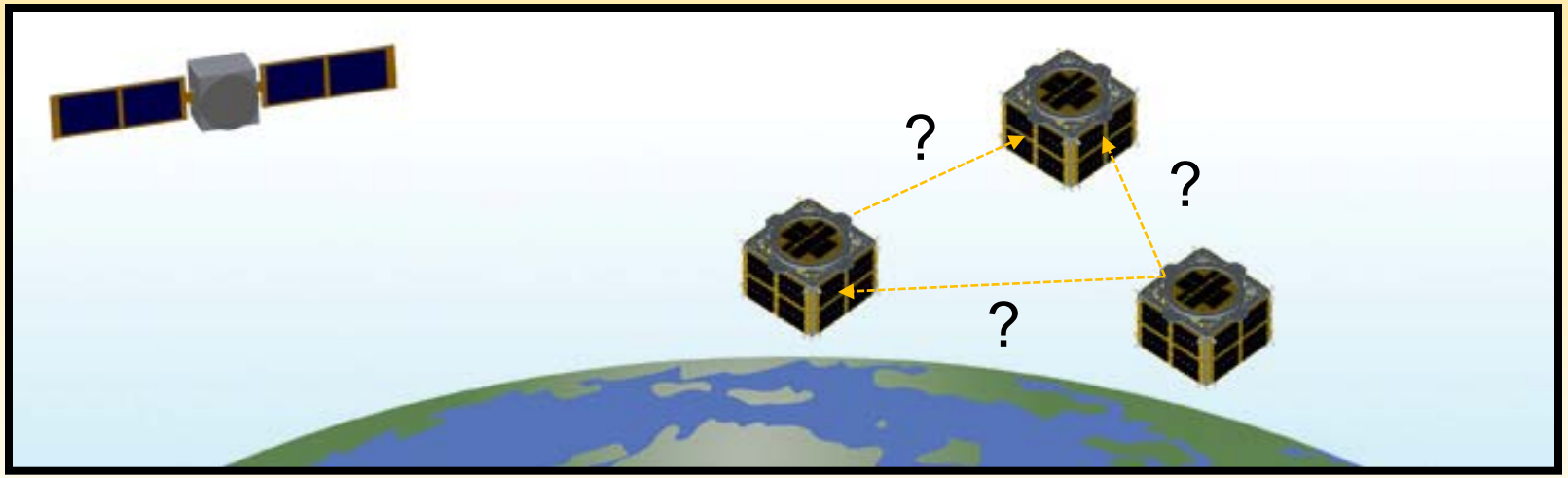
- L_a can be set to 1 to estimate a lossless system
- G_R is the gain of the receiving antenna
- σ is the scattering object specific cross section
- R_R is the distance from scattering object to receiver

G_R is the only parameter we control

Proximity Detection

Given right circumstances -> detect nearby objects?

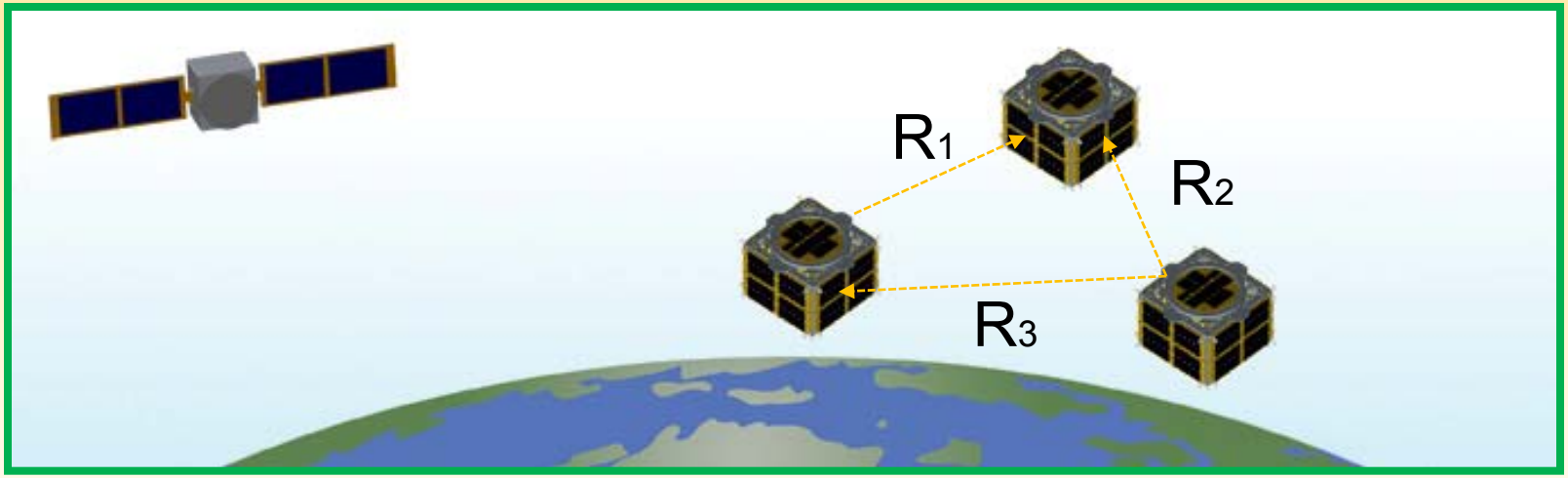
?



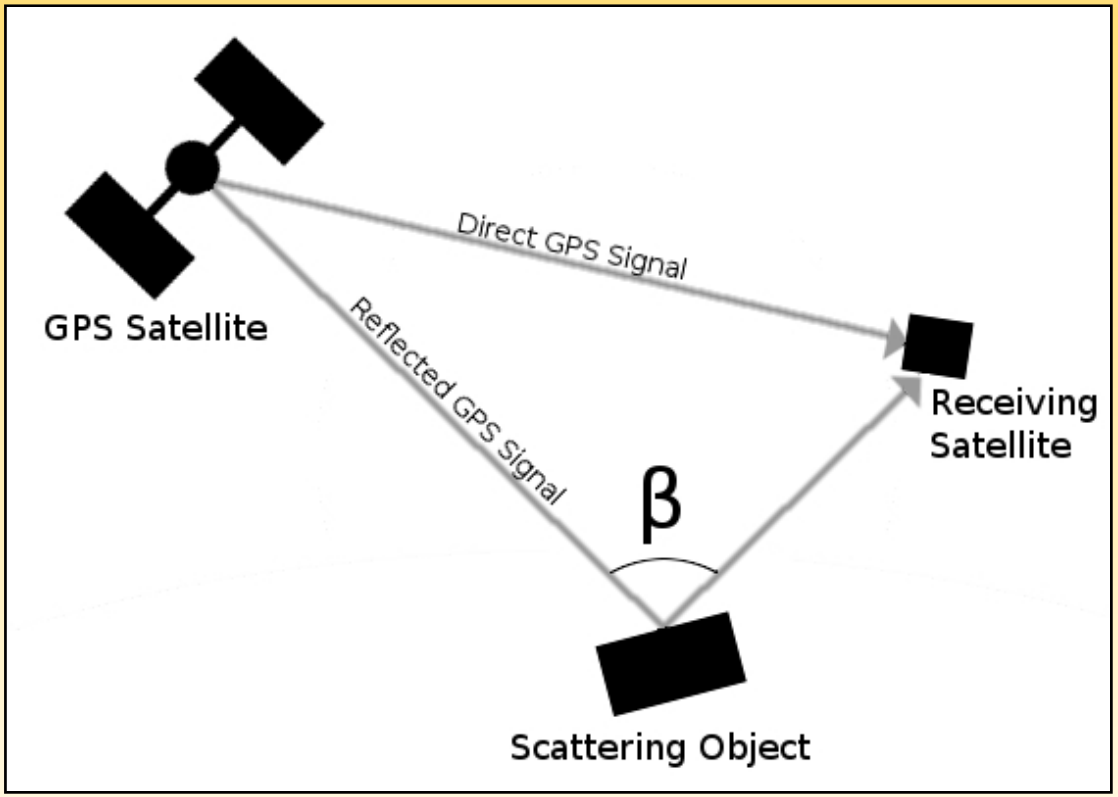
Proximity Detection

Given right circumstances -> detect nearby objects?

YES



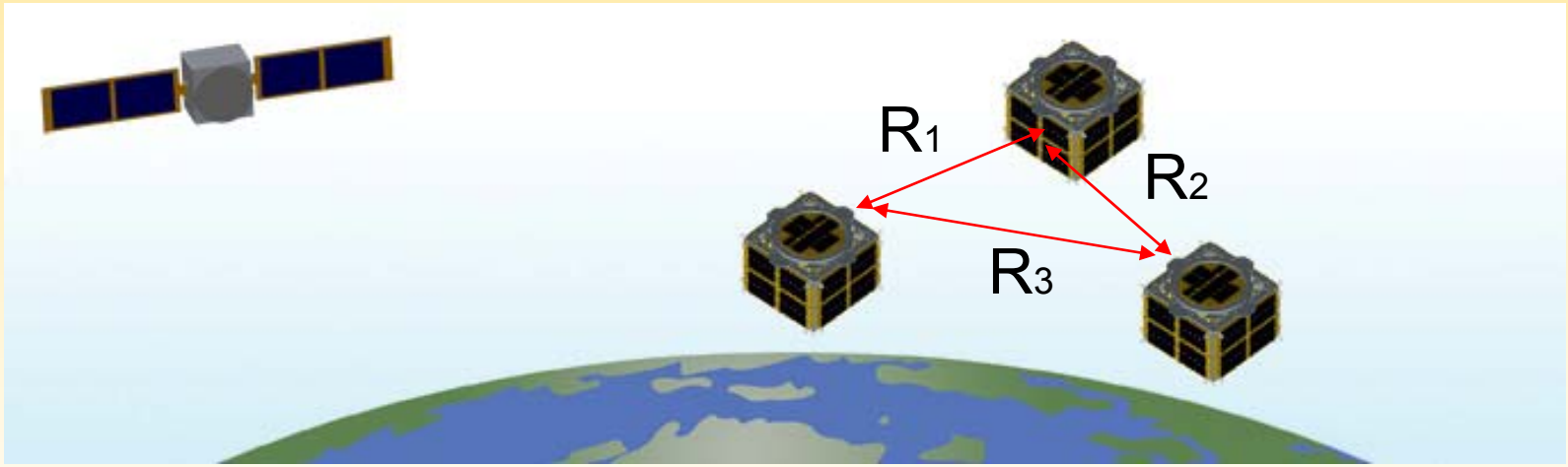
GPS Bistatic Geometry



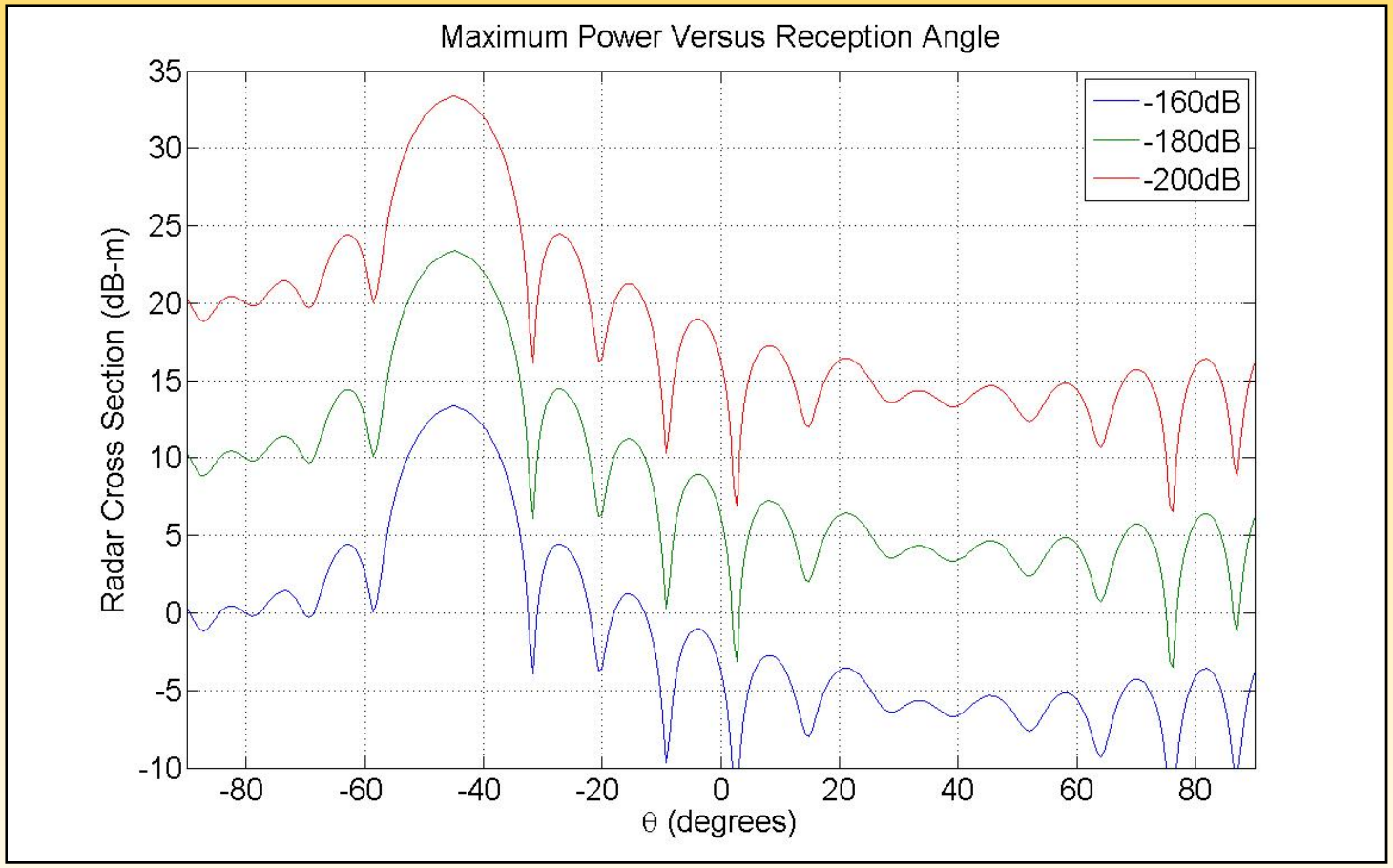
β is the angle between incidence and reflection and must be < π radians.

Proximity Detection

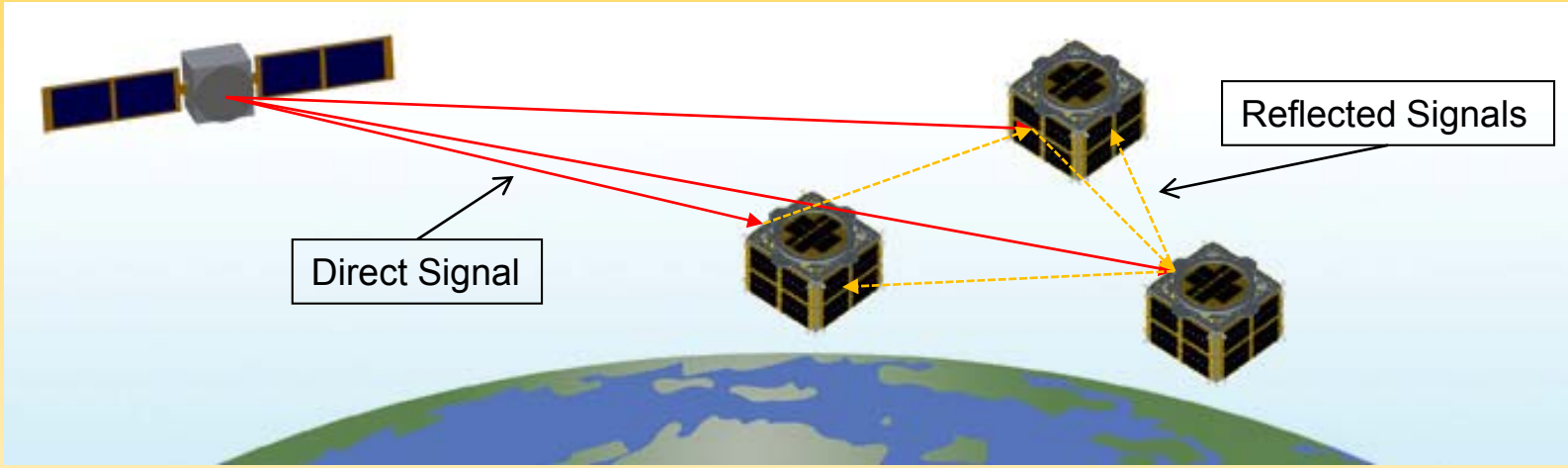
$$R_R = \sqrt{\frac{P_T G_T G_R L_a \lambda \sigma}{(4\pi)^3 R_T{}^2 P_R}}$$



Discernable Distance



Formation Operations



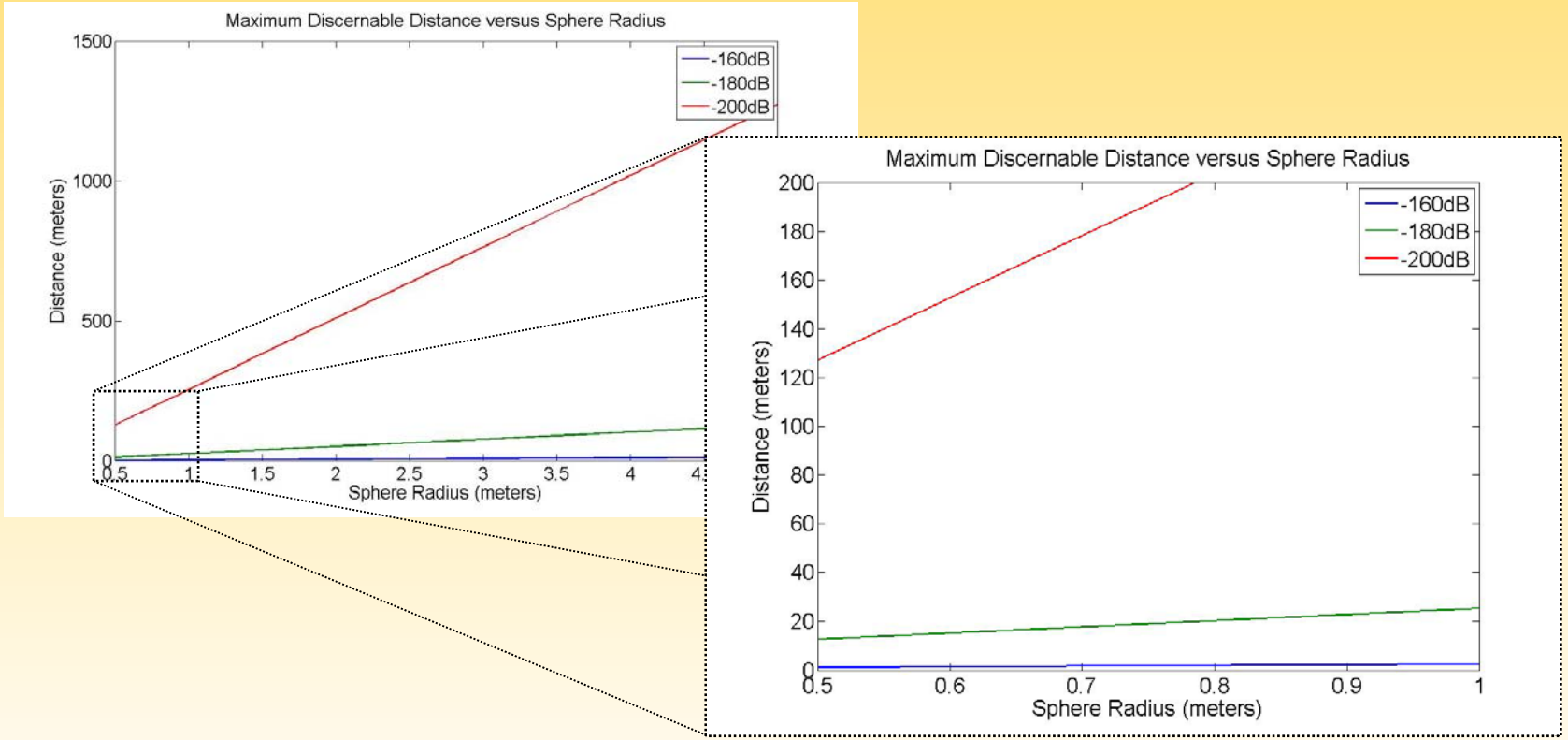
Clohessy-Wiltshire (CW) Equations:

$$\delta\vec{r}(t) = \vec{\Phi}_{rr}(t)\delta\vec{r}_0 + \vec{\Phi}_{rv}(t)\delta\vec{v}_0$$
$$\delta\vec{v}(t) = \vec{\Phi}_{vr}(t)\delta\vec{r}_0 + \vec{\Phi}_{vv}(t)\delta\vec{v}_0$$

Provide position and velocity of chasing satellite relative to target satellite.

Maximum Distance

Sphere: $\sigma = \pi r^2$



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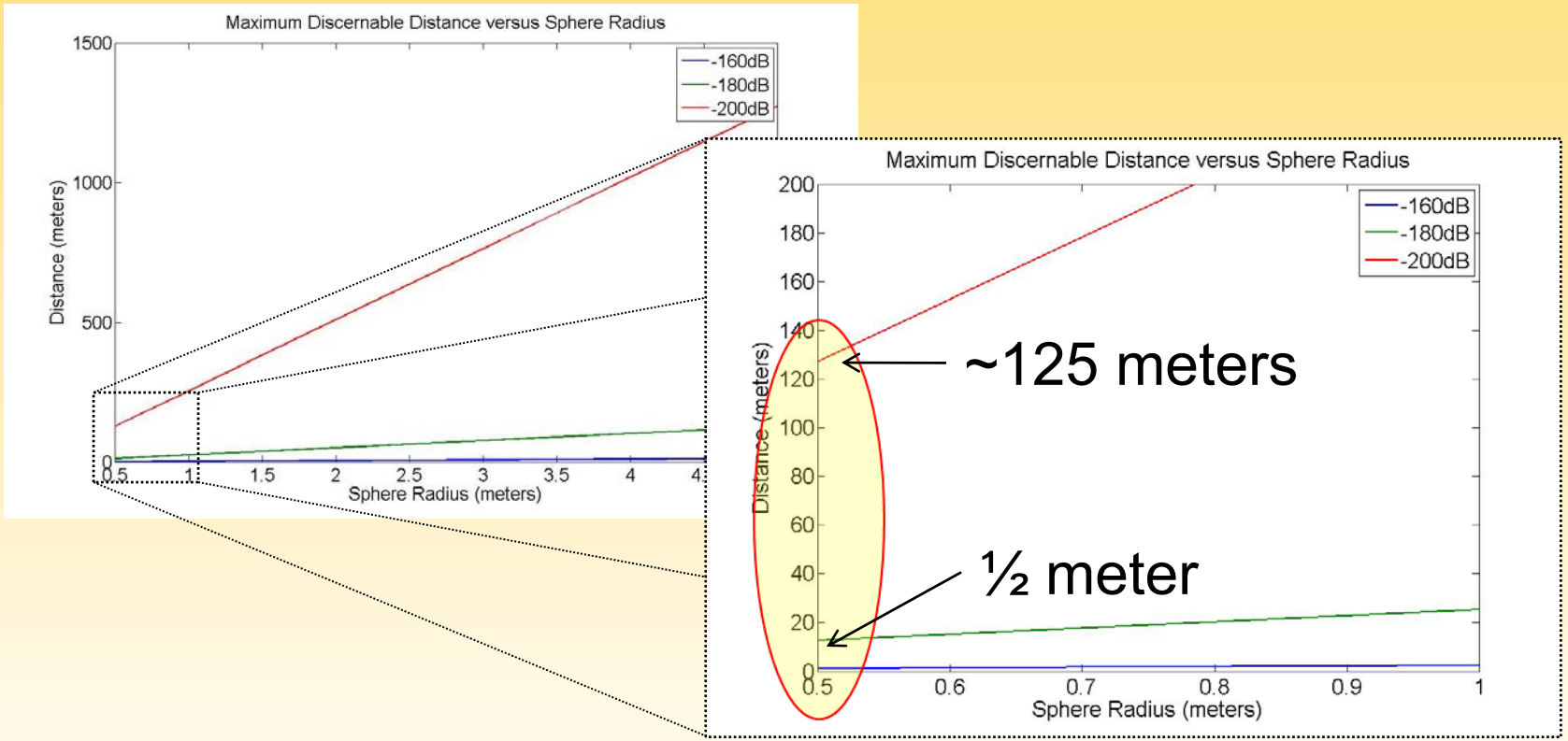
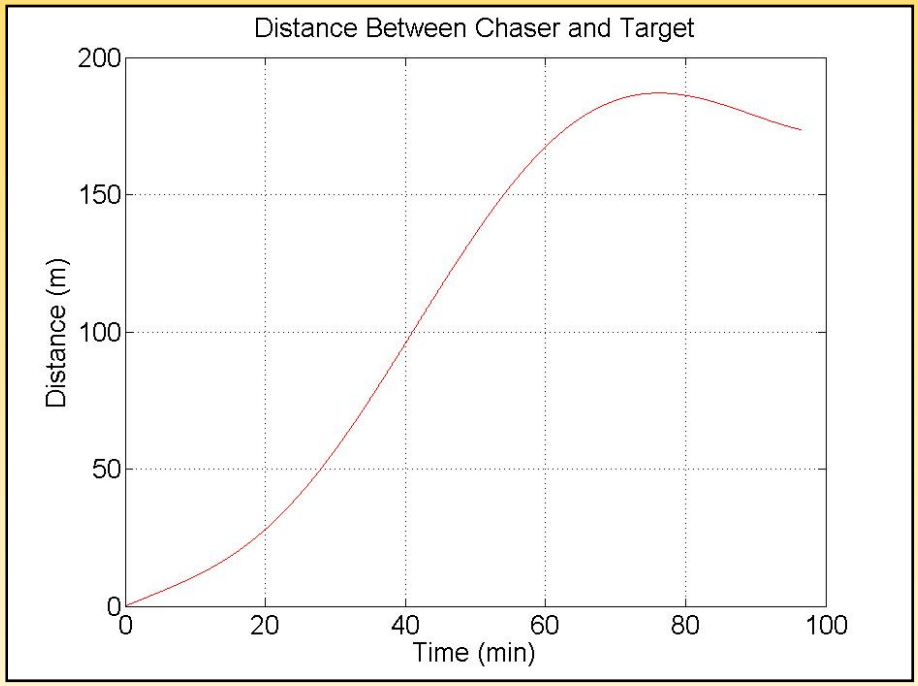
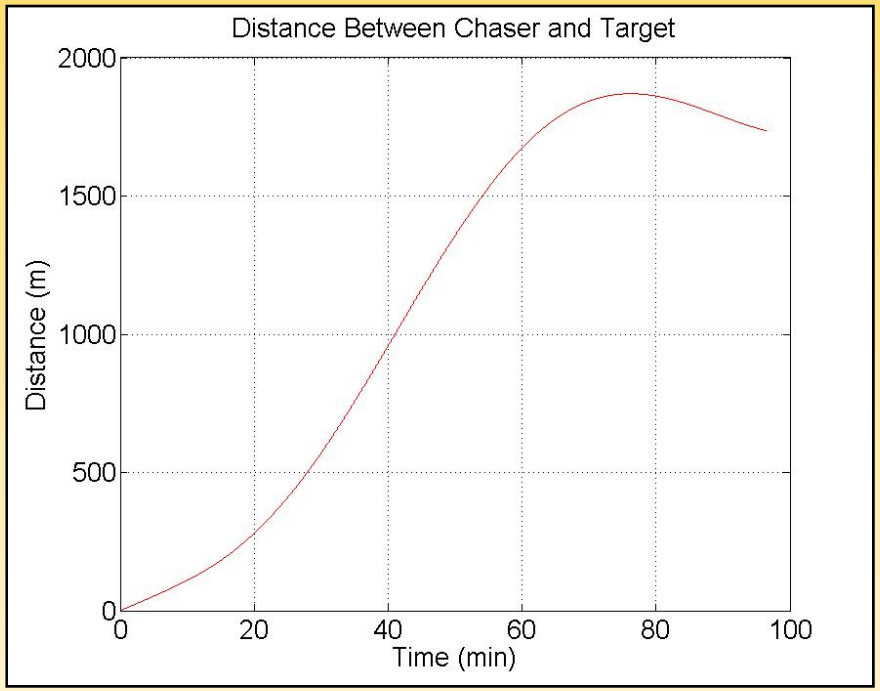


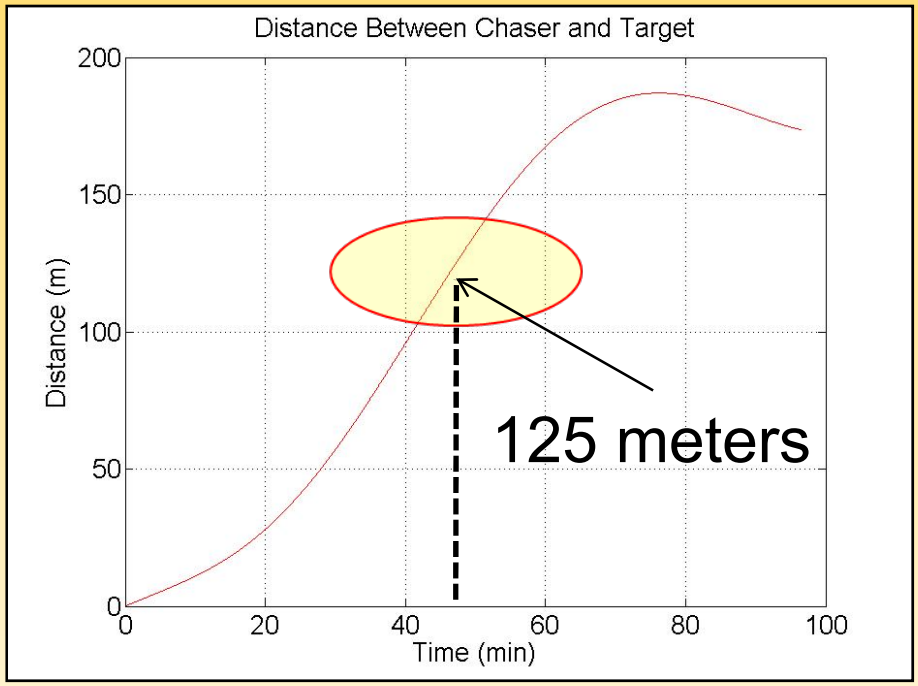
CW Results

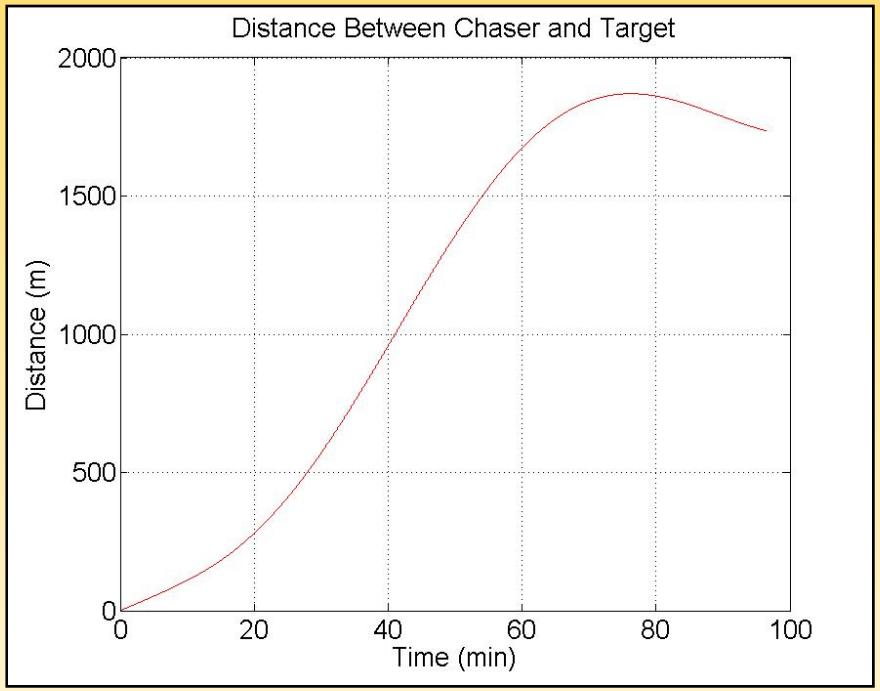




Initial velocity of right figure 10 times greater than initial velocity of left figure.

CW Results





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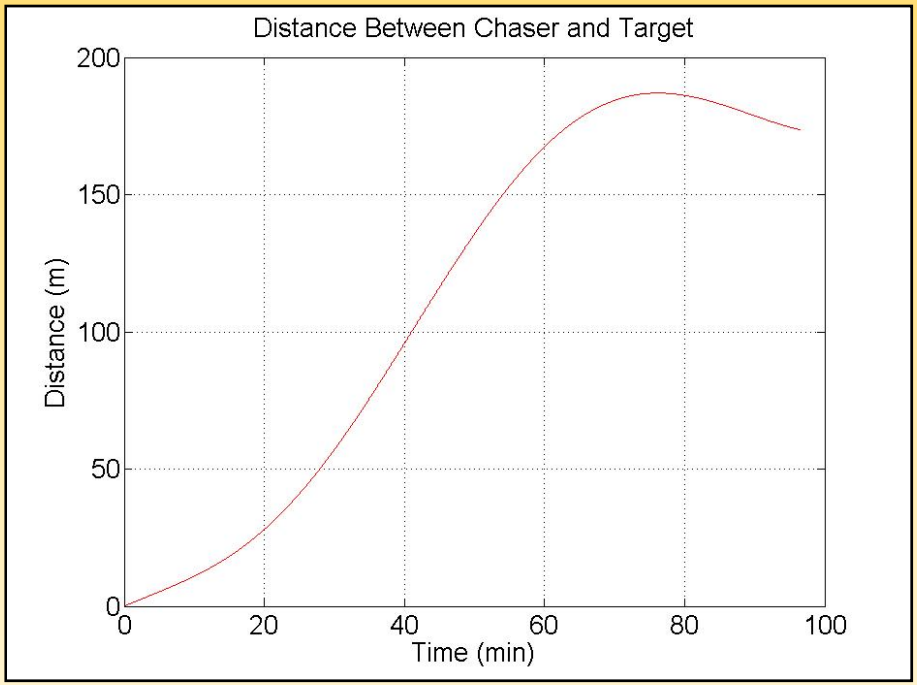

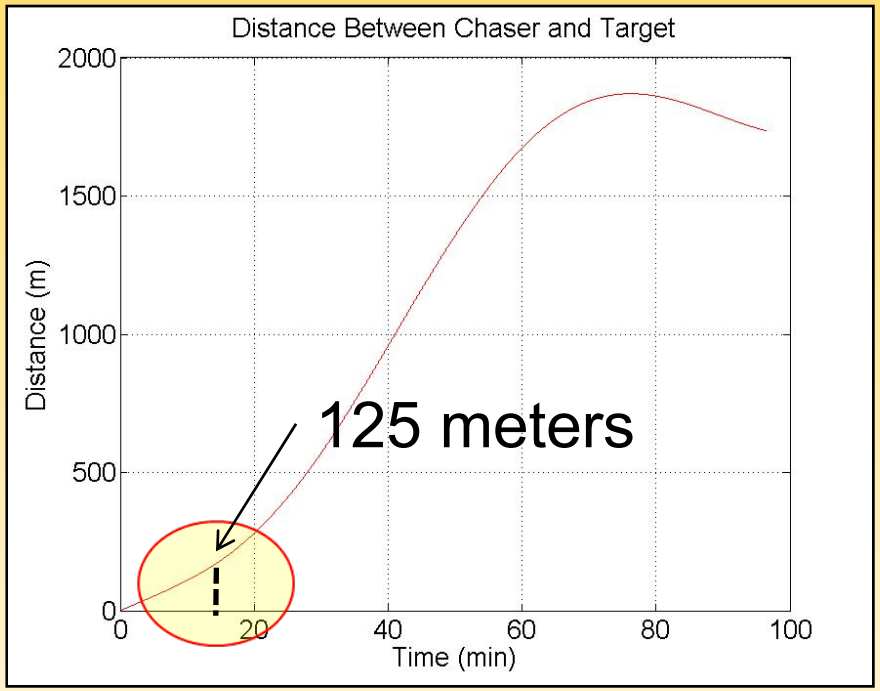

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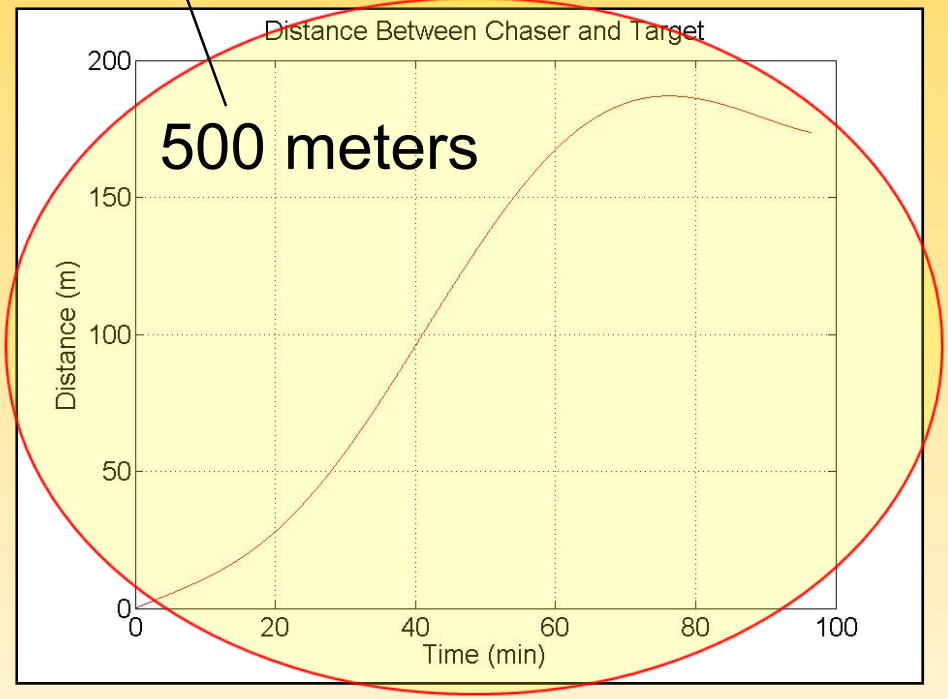
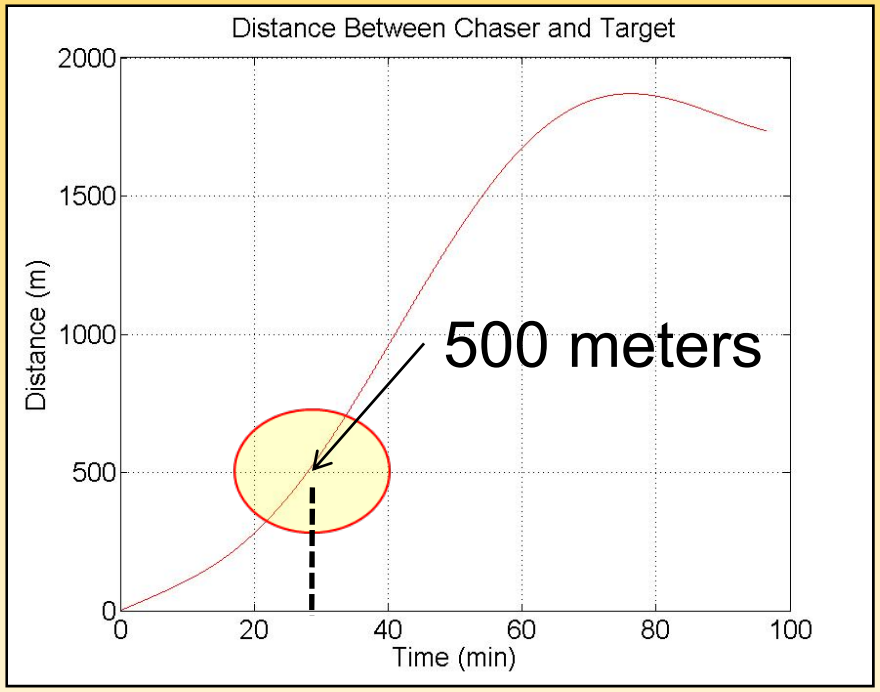
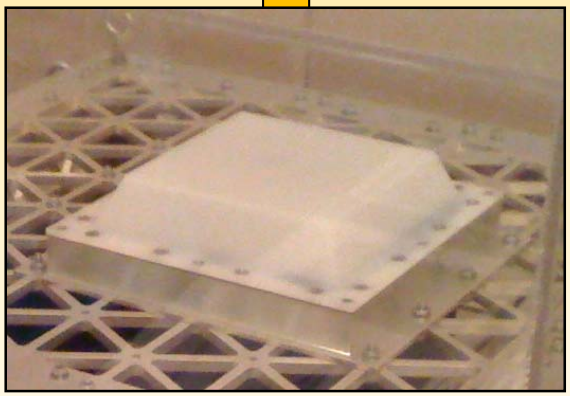




Initial velocity of right figure10 times greater than initial velocity of left figure.

GPS BR: Summary

- Inexpensive, mostly COTS, hardware
- Low power requirements
- Potentially very small hardware footprint



$$R_R = \sqrt{\frac{P_T G_T G_R L_a \lambda \sigma}{(4\pi)^3 R_T^{\,2} P_R}}$$

Only able to impact G_R with hardware

Ongoing and Future Work

- Low Power: less than -160 dBW
- Reflection/Scattering power loss
- Mismatched Polarizations

- Smaller cross sections require better antennas

Small Sat. GPS Bistatic Radar

Acknowledgements

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- AFRL
- NASA-MN Space Grant

Questions?