Using North Korean Missile Development to Enhance Student Interest in Kinematics and Newtonian Mechanics

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Recent Events

Missile Development

May 14th 2017- Hwasong-12 Launch – Japan, Guam

July 4th 2017 - Hwasong-14 Launch – Anchorage

July 28th 2017 - Hwasong-14 Launch - Seattle

Nov 29th 2017 - Hwasong-15 Launch – San Diego, Washington, etc

Nuclear Submarine Development

Nuclear Weapons Development

Aug 6th 1945 – 15 kt, for comparison purposes

Oct 9th 2006 – 0.7 kt, maybe a fizzle

May 25th 2009 – 5.4 kt

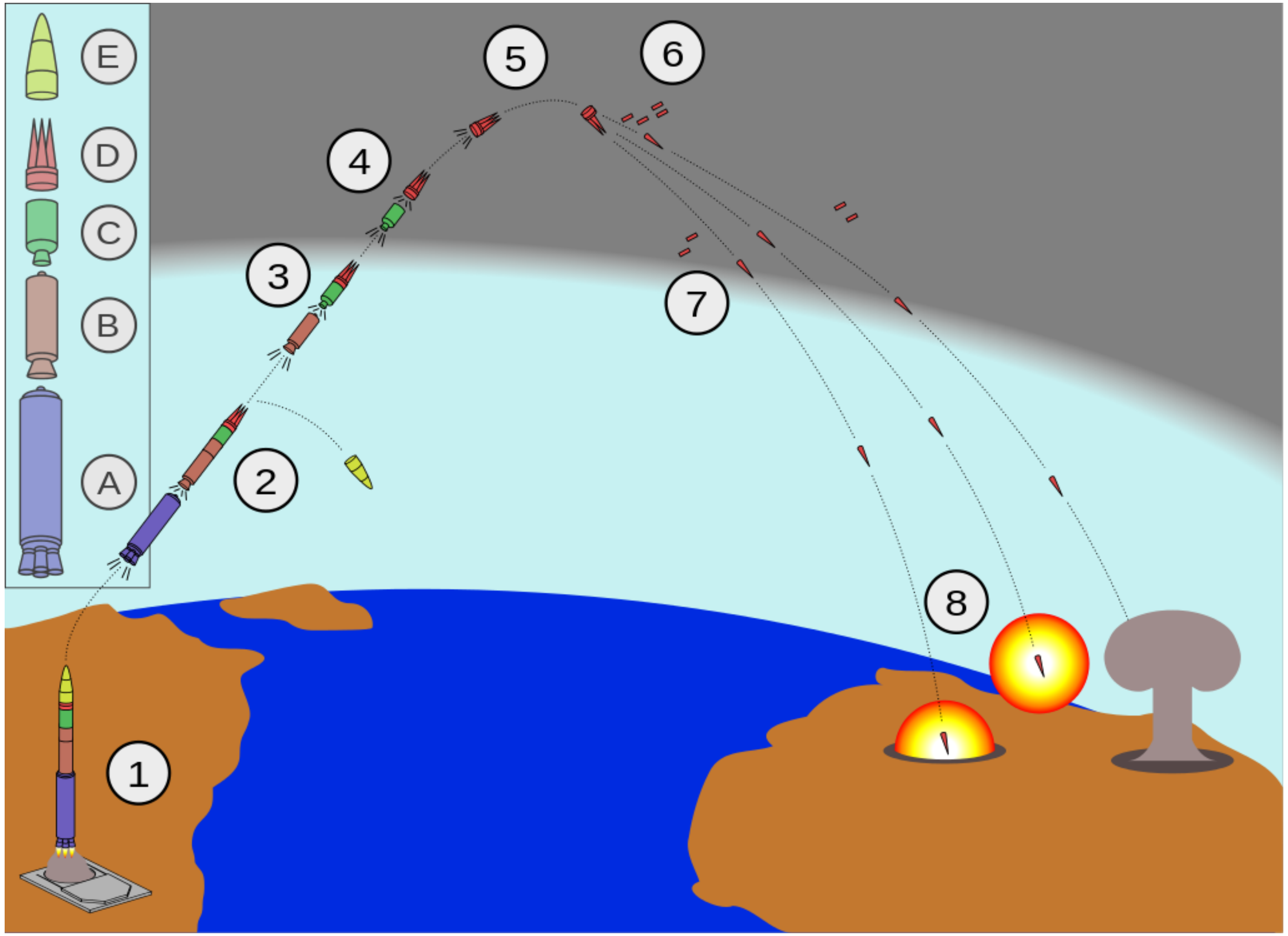
Feb 12th 2013 – 14 kt

Jan 6th 2016 – 10 kt

Sept 9th 2016 – 25 kt, claimed to be small enough for use as a warhead on a missile

Sept 3rd 2017 - >100 kt (wide range of estimates), claimed to me a hydrogen bomb and it generated a tremor of magnitude 6.1. (Double Tremors)

Intercontinental Ballistic Missiles



Wikipedia, Dec. 2017 – “Ballistic Missile”

Minuteman-III MIRV launch sequence :

1. The missile launches out of its silo by firing its 1st-stage boost motor (*A*).
2. About 60 seconds after launch, the 1st stage drops off and the 2nd-stage motor (*B*) ignites. The missile shroud (*E*) is ejected.
3. About 120 seconds after launch, the 3rd-stage motor (*C*) ignites and separates from the 2nd stage.
4. About 180 seconds after launch, 3rd-stage thrust terminates and the Post-Boost Vehicle (*D*) separates from the rocket.
5. The Post-Boost Vehicle maneuvers itself and prepares for re-entry vehicle (RV) deployment.
6. The RVs, as well as decoys and chaff, are deployed.
7. The RVs (now armed) and chaff re-enter the atmosphere at high speeds.
8. The nuclear warheads detonate.

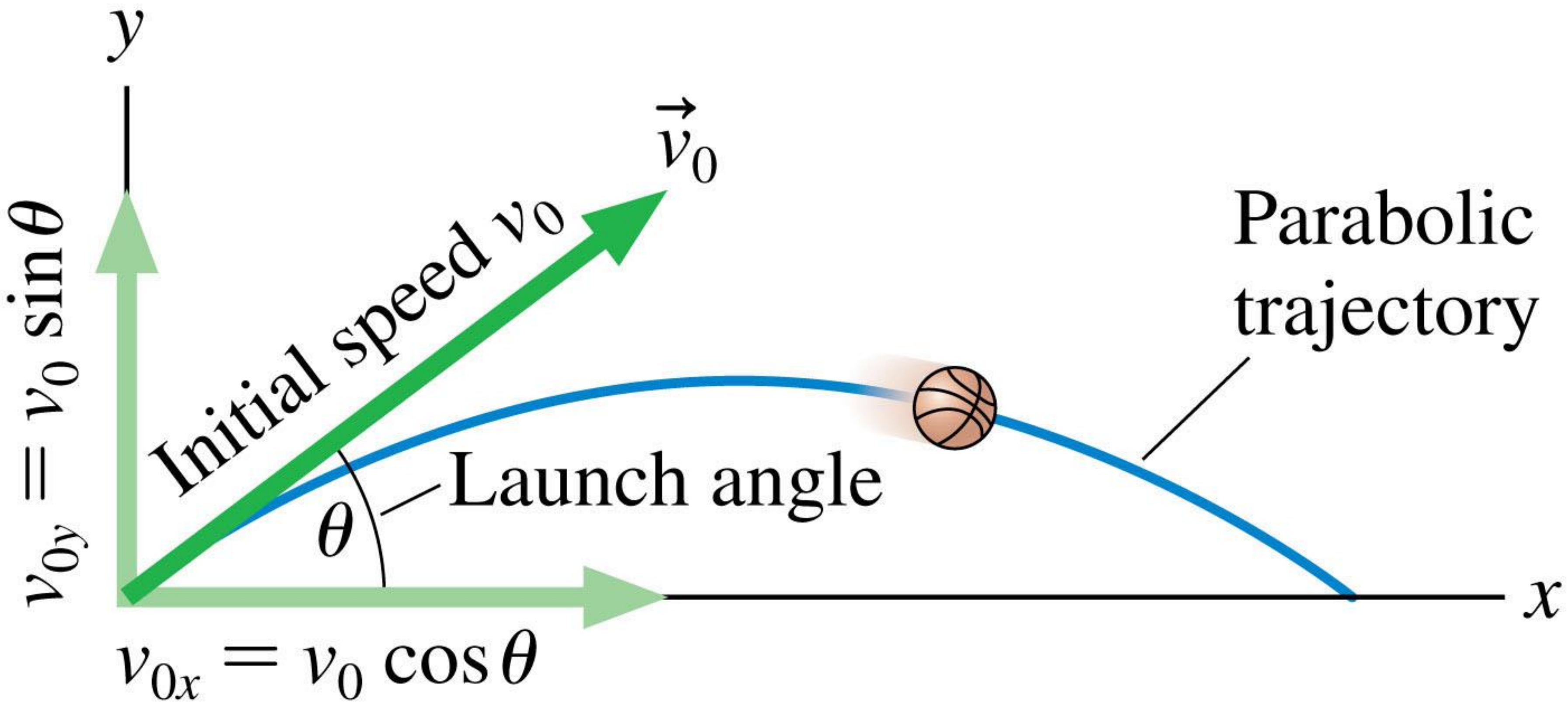
Korean Launch Data

Data	May 14th	July 4th	July 28th
Time of flight	30 min	37 min	47 min
Horizontal Distance	787 km	933 km	998 miles
Altitude (Apogee)	2111.5 km	2802 km	3724.9 km
Possible Range	4000 to 6000 km	6700 km	10000 km
Missile Type	Hwasong-12	Hwasong-14	Hwasong-14
Landing Site	Sea of Japan	Japan's exclusive economic zone	Near Hokkaido, Japan
Launch Site	Kusong test site	Panghyon Aircraft near Panghyon Airport	Chagang Province

Korean Launch Data

Data	Aug 29th	Sept 15th	Nov 29th	
Time of flight		17 min	53 min	
Horizontal Distance	2700 km	3700 km	950 km	
Altitude	550 km	770 km	4475 km	
Possible Range				
Missile Type	Hwasong-12	Hwasong-12	Hwasong-15	
Landing Site	Past Hoddaido	Past Hokkaido,	Japan's exclusive economic zone	
Launch Site		Sunan Airfield	Pyongsong	

Projectile Motion as Commonly Presented in Physics Classes



Randell D. Knight, "Physics for Scientists and Engineers," taken from Mastering Physics, Pearson, 2017

Solving the simple problem

Vertical Motion

$$t_f = \frac{2v_0 \sin\theta}{g}$$

$$h = \frac{v_0^2 \sin^2\theta}{2g}$$

Horizontal Motion

$$range = \frac{v_0^2 \sin 2\theta}{g}$$

$$range_{\max} = \frac{v_0^2}{g}$$

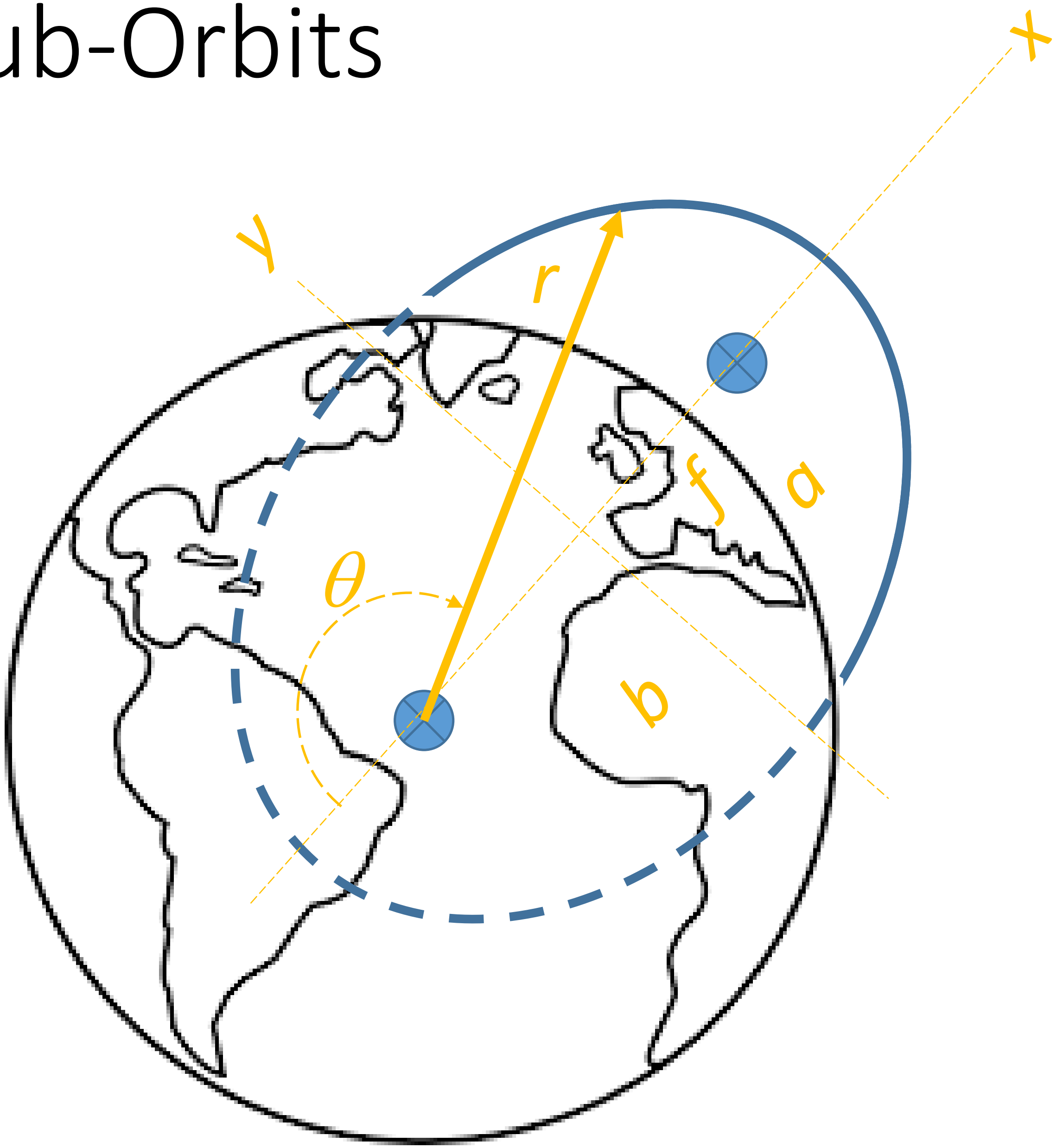
when $\theta = 45\deg$

Approximations when applied to ballistic missiles

Approximations when applied to ballistic missiles

- Flat Earth
- Constant Acceleration Due to Gravity
- Time for rockets to fire
- Effects of drag while in the atmosphere
- Effects of the Earth’s rotation

Kepler's Sub-Orbits



Inverse Square Law and Ballistics

$$F_g = G\frac{M_E m}{r^2}$$

Conservation of Energy and

Angular Momentum

$$2h = \dot{r}^2 + \frac{l^2}{r^2} - \frac{2\Omega}{r}$$

$$l = r^2\dot{\theta}$$

Where:

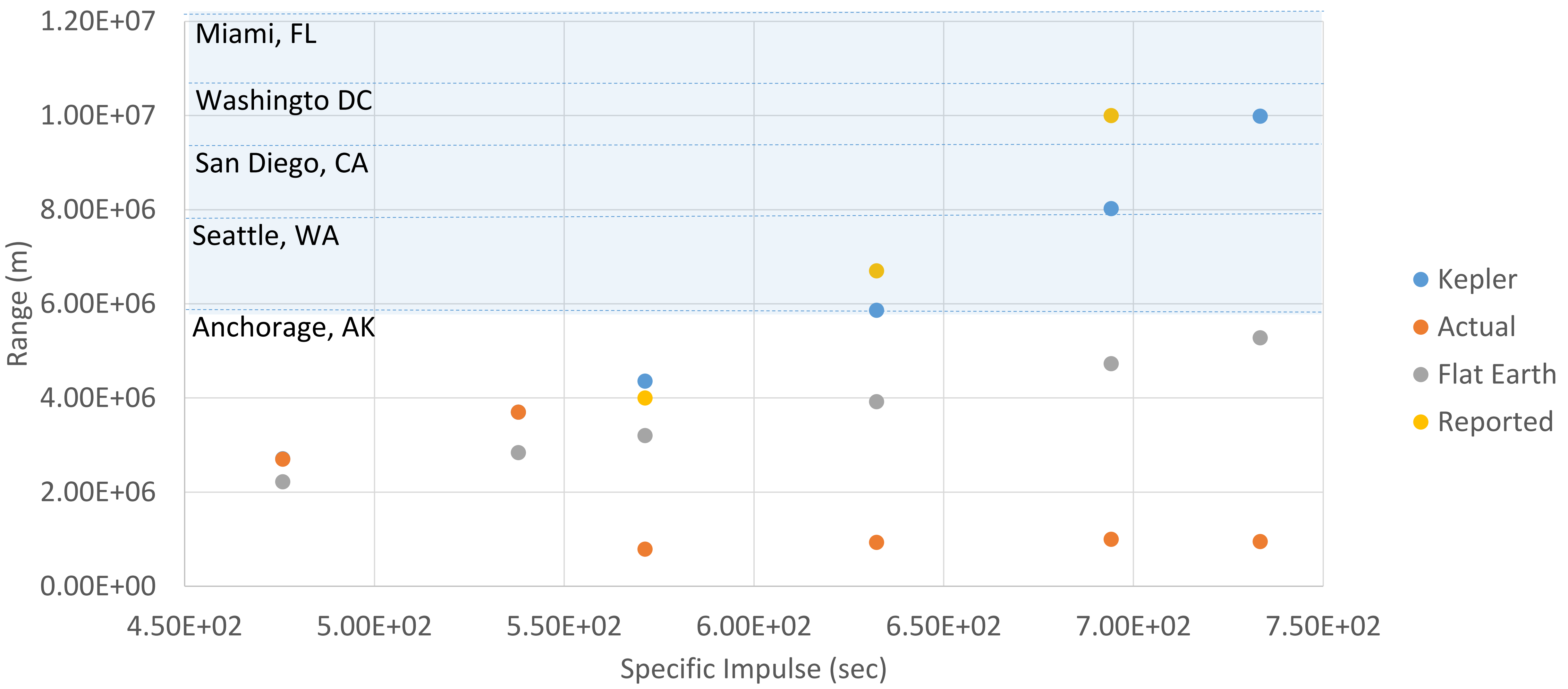
$$h = \frac{E}{m},\ l = \frac{L}{m},\ \Omega = GM_E$$

This leads to Kepler's laws

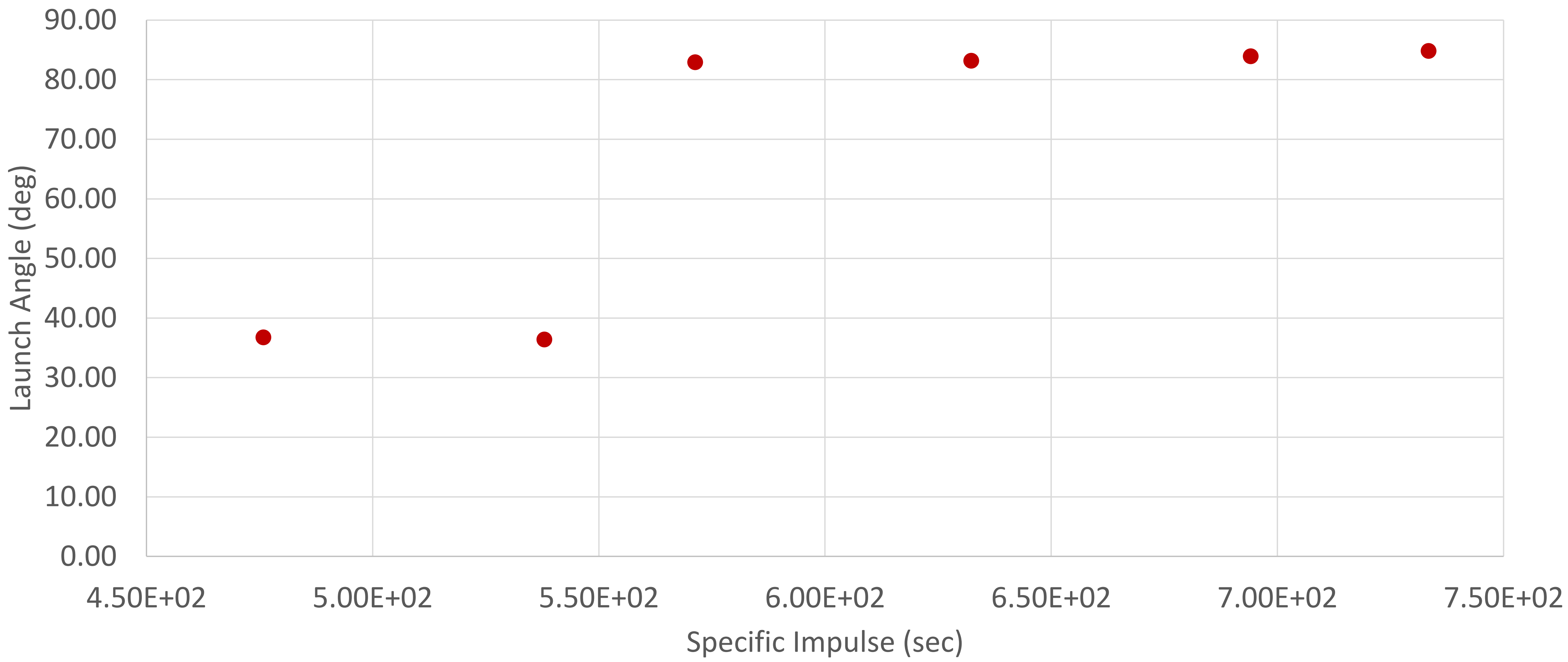
$$\frac{1}{r} = A\cos\theta + B$$

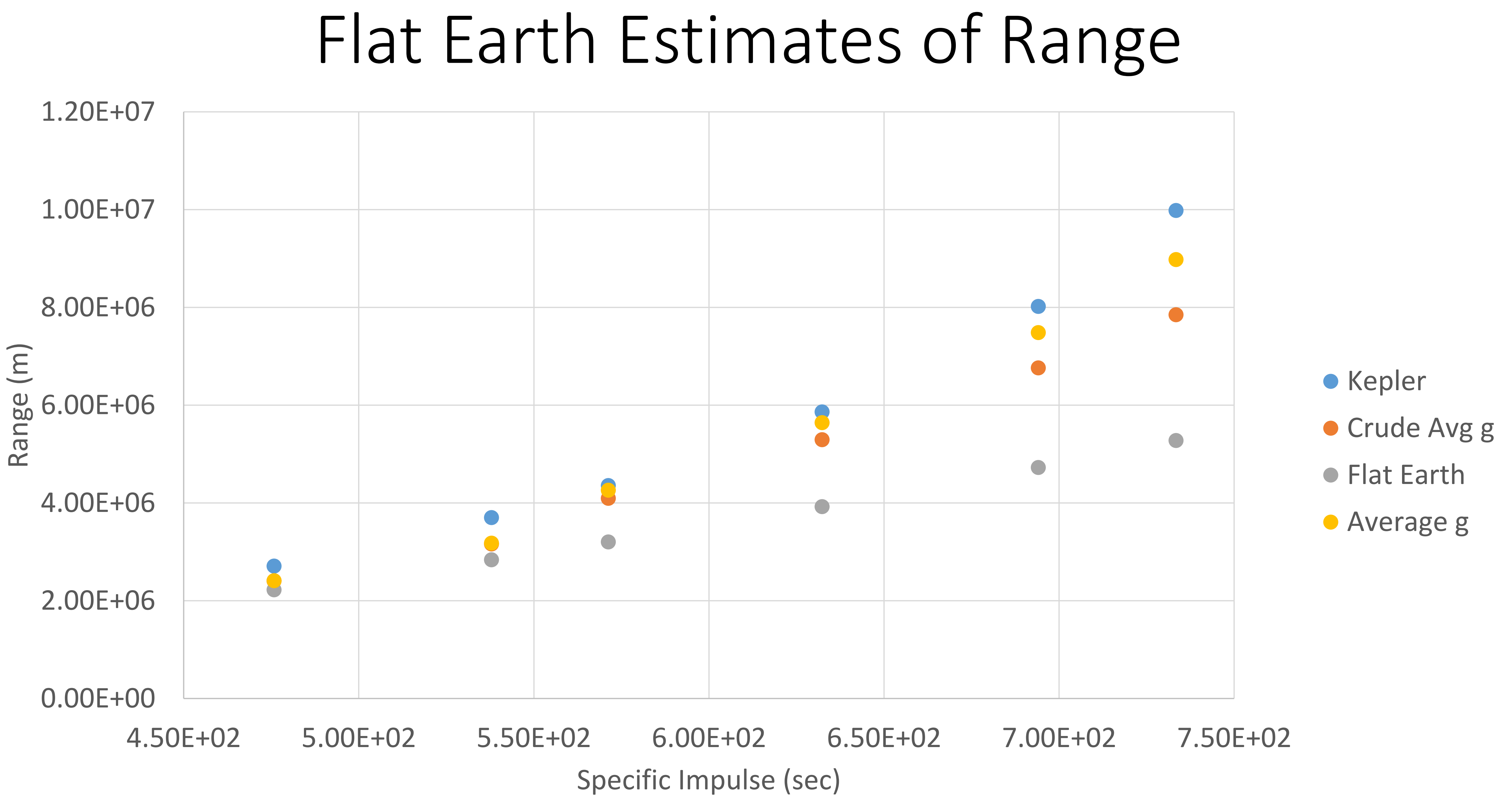
$$\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 = 1$$

Range vrs Specific Impulse
Reported, Maximum, Flat Earth



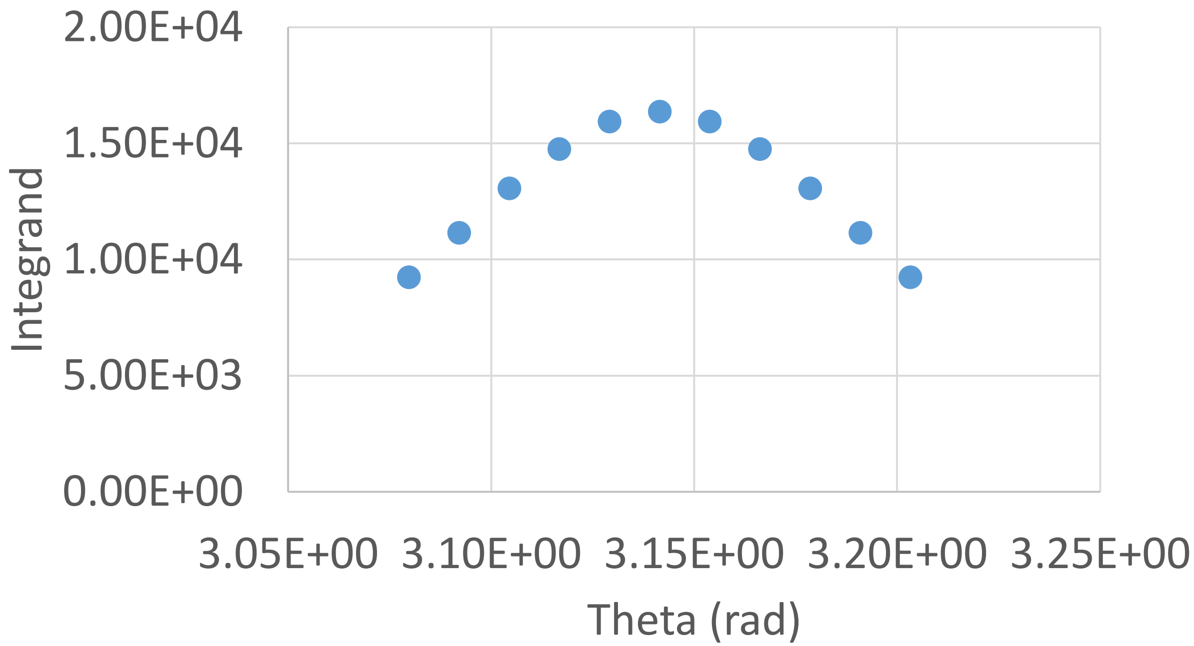
Launch Angles vrs Specific Impulse





Flat Earth Estimates of Range
Range (m)
1.20E+07
1.00E+07
8.00E+06
6.00E+06
4.00E+06
2.00E+06
0.00E+00
4.50E+02
5.00E+02
5.50E+02
6.00E+02
6.50E+02
7.00E+02
7.50E+02
Specific Impulse (sec)
Kepler
Crude Avg g
Flat Earth
Average g

Computing Time of Flight



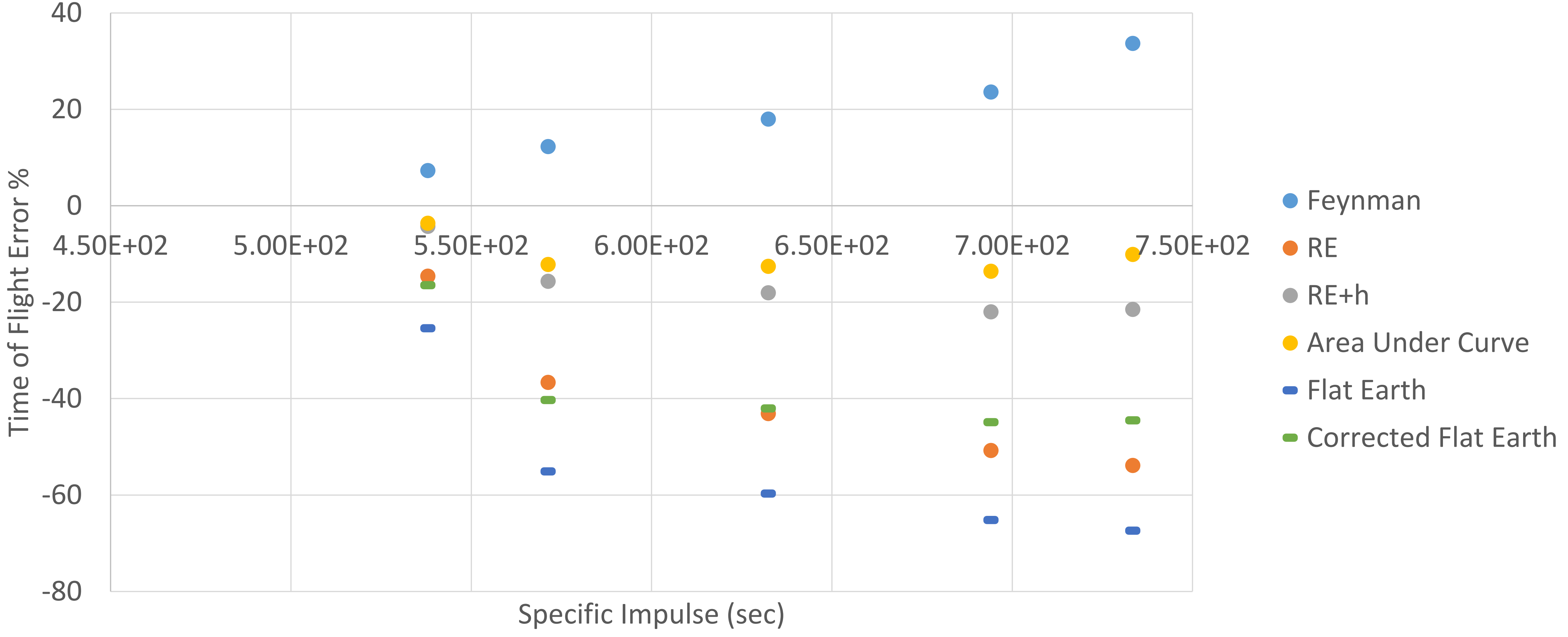
$$t_{flight} = \frac{1}{l} \int_{\text{launch}}^{\text{target}} \frac{d\theta}{(A\cos\theta + B)^2}$$

$$\Delta t = \frac{r^2 \Delta\theta}{l} = \frac{(R_E + h)^2 \,\text{Range}}{l \cdot \text{R}_\text{E}}$$

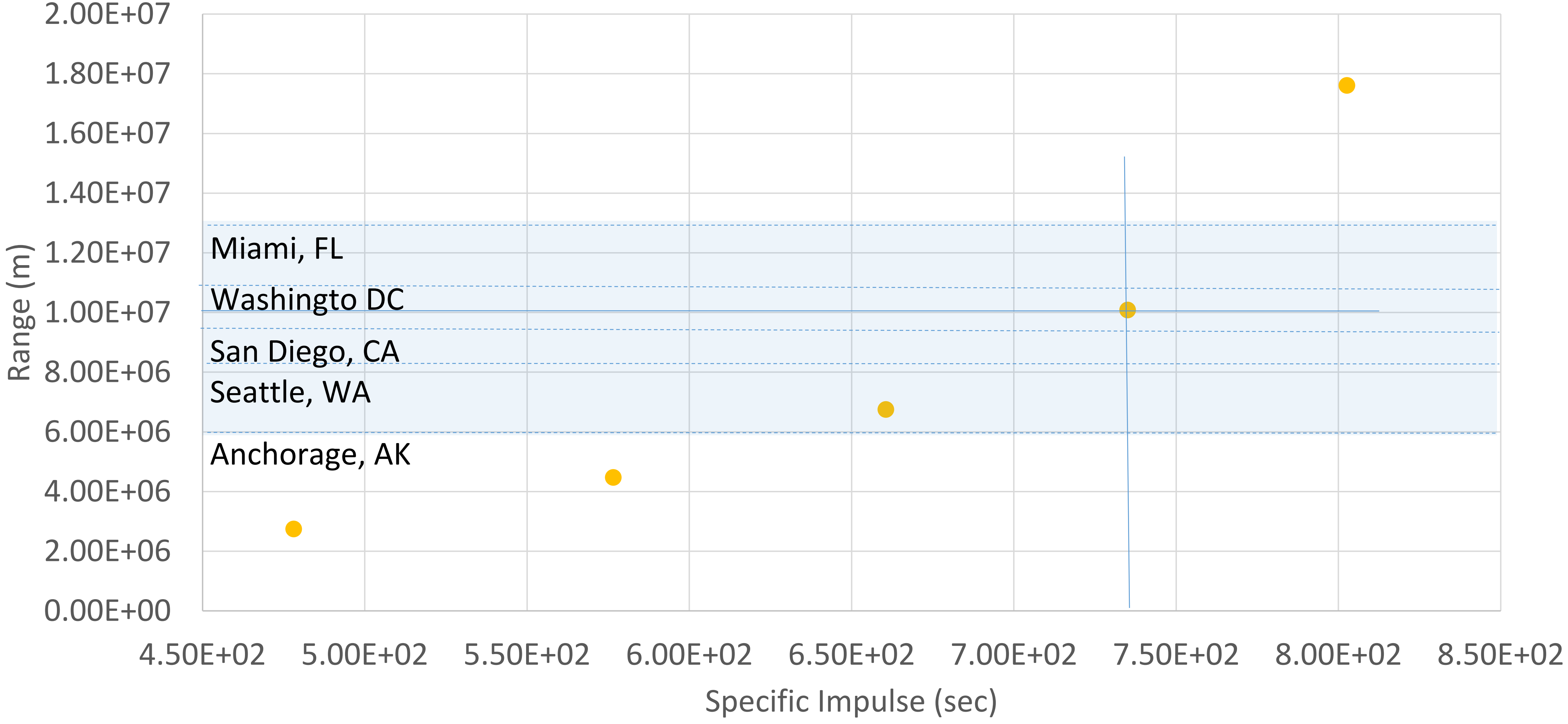
or use the area under the curve!

$$\approx \frac{(2R_E^2 + 2R_E h + h^2)\text{Range}}{2l \cdot \text{R}_\text{E}}$$

Time of Flight Errors



Range vrs Specific Impulse



Conclusions and Extensions

- Lots of opportunities for student projects and labs
- Kinematics, momentum, energy, angular momentum, modelling, data
- Models some possible career paths, data analytics, analysis

Improvements and Similar Labs I'm using

- Finite engine burn time.
- Atmospheric Drag
- Massing the Sun with planetary orbits. (Can include error analysis, hypotheses testing.)
- Massing binary Stars (Rigel). (Can include error analysis, hypotheses testing)

Thanks