StellarXplorers

Sample Exercise #4
Mission Requirements
"Get the Ticker Up & Running"

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Sample Exercise Synopsis

Teams will be required to select a launch service to place a satellite into orbit. A launch service is made up of the rocket launch, and all the logistics and other requirements to support that rocket launch. There may be impacts to the satellite depending on which launch service option is chosen. Teams whose choices meet the mission requirements with the least expensive launch option will achieve high scores in this sample exercise.

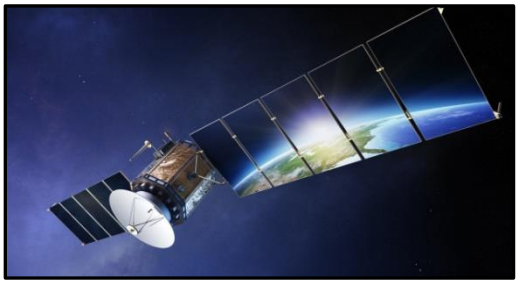
Disclaimer: Information in this briefing was developed specifically for use during the StellarXplorers Challenge. Although some information was collected from publicly available sources, any similarity between items in this presentation and real-world events is purely coincidental.

Mission Briefing

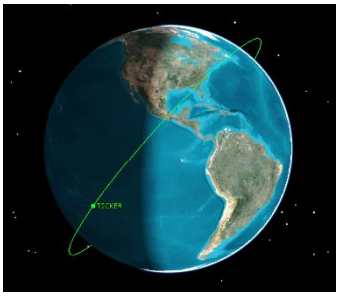
Launch Vehicle Selection

Note: The StellarXplorers Staff highly recommends that teams read the entire scenario before beginning their analysis.

The Situation:



The financial consortium, **World Financial Systems, Inc.**, has been very satisfied with the results from their first spacecraft, **TICKER,** and are ready to commit to an even bigger satellite with more capability. They want to send more data to many more Stock Exchanges around the World from their new satellite, **TICKER 2**, and hope to launch it within the next 24 months. This spacecraft is being built by ***Expanse Space Systems*** of Ceres, Illinois, the same company that built **TICKER**. As part of the **World Financial Systems, Inc.** contract, ***Expanse Space Systems*** must select a launch vehicle to place **TICKER 2** into orbit and has received proposals from two launch service providers. Each rocket has its own unique capabilities and limitations. ***Expanse Space Systems*** needs to select the best launch service for **TICKER 2** while still meeting the budget limitation set by **World Financial Systems, Inc.** The total budget for the launch vehicle and all launch operations is $175,000,000.



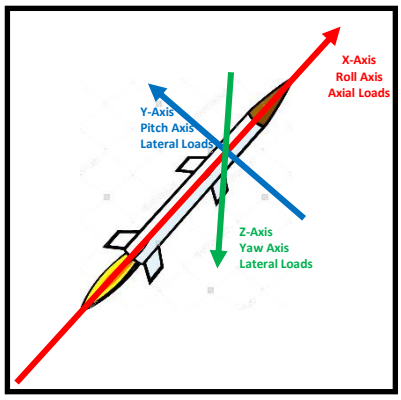
The spacecraft is to be launched into a circular orbit at an altitude of 1,000 kilometers (621 miles) and an Inclination of 50°. **TICKER 2** will have an orbital period of 105.119 minutes, so it will orbit the Earth 13.7 times in 24 hours. This orbit will allow the satellite to contact each of the many world Stock Exchange locations several times each day and will allow a significant amount of data to be received from and shipped to each of the Exchanges.

To reach this orbit, a high-performance rocket is needed. Launch vehicles are a commodity and they are bought “off the shelf”. The rocket itself is not unique and not completely designed for each mission. A satellite’s unique requirements, such as doors in the payload fairing, the method of attaching the satellite to the rocket, the satellite’s electrical interface wiring to the rocket, and other minor items can be modified on the launch vehicle. However, the basic rocket (1st & 2nd stages and its avionics) has been designed and built and so, is locked in stone.

The Task:

Select a launch service for the **TICKER 2** spacecraft. **EXPANSE SPACE SYSTEMS** has hired your team to evaluate the two potential launch services and has requested that you make a recommendation on which option would provide the best opportunity to meet all mission requirements at the lowest price. You will be judged on final cost at liftoff, which will be a combination of the total costs for the rocket chosen and any launch delays.

Satellite Launch Environment:



Satellites usually face a "rough" ride into orbit on their rockets. Forces acting on the satellite can literally shake it to pieces if it has not been designed correctly and tested to withstand those forces. These forces include "Axial Loads" cause by the acceleration of the rocket and occur along the long axis (X-Axis) of the rocket. The satellite must also deal with "Lateral Loads" caused by the sideways pitch and yaw motions of the rockets along the Y & Z Axis's. Also, the satellite can receive a "Shock Load" from a sudden event on the vehicle such as the firing of explosive bolts to separate the first and second stages of the rocket or to release the satellite from the launch vehicle. All these loads are measured in g's. One g is one times the force of gravity. For example, a five-pound weight sitting on a table exerts 5 pounds of pressure on the table in 1 g. At 2 g's, the weight exerts 10 pounds of pressure on the table. 3 g's = 15 pounds, 4 g's = 20 pounds, and so on. Finally, the satellite can experience "Acoustic Loads" from the rocket. These acoustic loads are caused by very large sound waves (think absurdly loud, make your ears bleed rock concert). These sound waves come from the noise of the rocket's engines or the sound of the air rushing past the payload fairing. Acoustic levels are measured in Decibels (dB).

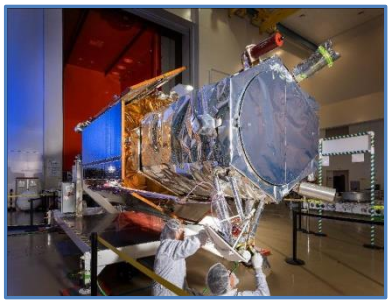
The **TICKER 2** satellite is built to withstand an Axial Load of 5.7 g's, a Lateral Load of 1.7 g's, and a Shock Load of 3,400 g's. The satellite will be tested to a maximum Acoustic Load expected inside the payload fairing of 137 dB. Some of these loads can be improved by modifying the launch vehicle, such as by adding acoustic blankets inside the fairing for the noise or adding shock reduction mechanisms for separating the satellite from the rocket. However, these alterations may result in reduced launch vehicle performance, lengthen the time to prepare for launch and increase the launch costs. These will be outlined in each launch vehicle's summary.

Different launch vehicles have different capabilities and environments, but all proposed rockets have enough basic performance to put the **TICKER 2** into its required orbit. However, the team must not recommend a launch vehicle which exceeds the environments the satellite is designed to experience, the total payload mass limit of the

rocket, or the payload fairing volume requirements for the **TICKER 2** satellite. There is neither the time nor the money to make major modifications to the basic satellite. The team's efforts should focus on the most cost-effective launch vehicle that can get the **TICKER 2** on orbit.

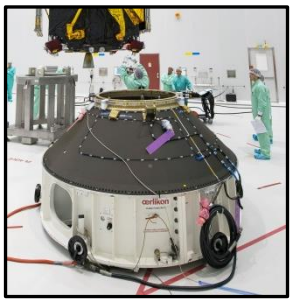
Satellite Launch Requirements:

The spacecraft weight is 1,675 kilograms (3,693 pounds). In its launch configuration, **TICKER 2** is 2.5 meters (m) in diameter and 5.0 m in height. As mentioned earlier, the mission orbit is at a 50º inclination with a 1,000-kilometer circular orbit. After **TICKER 2** is deployed, launch cost reducing tasks, such as Secondary Satellite deployment, can be performed.



EXPANSE SPACE SYSTEMS will complete construction and testing of **TICKER 2** on August 15, 2021. At that point, they will be ready to ship the satellite to the launch site. If the launch vehicle is not ready, **EXPANSE SPACE SYSTEMS** will store the spacecraft in one of its clean rooms until the rocket is ready. They will continually monitor the status of the spacecraft to make sure it has not been contaminated or damaged. Every 45 days, **EXPANSE SPACE SYSTEMS** will run a short test on the satellite to verify all its systems are still functional. **EXPANSE SPACE SYSTEMS** will charge **WORLD FINANCIAL SYSTEMS, INC.** $15,000 per day to store **TICKER 2** at their facility.

Payload Attach Fitting:



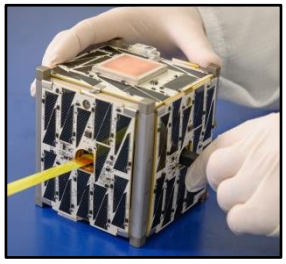
The top of the launch vehicle and bottom of the satellite are not identical. This requires some type of structure that will match the interface of each vehicle. This structure is called the Payload Attach Fitting (PAF). Not only should it provide the mechanical interface between the rocket and the satellite, the PAF also carries the electrical interface between both vehicles. It must be sturdy enough to carry the Axial Loads of the spacecraft and rigid enough so that it does not introduce additional Lateral Loads to the satellite. On the other hand, it should be light enough to not significantly increase the launch mass of the mission. Each launch service provider has a PAF which matches the **TICKER 2** interface and is included in the cost of the launch vehicle. However, the PAF is considered part of the payload and therefore must be accounted for in the satellite mass allocation.

Launch Insurance:

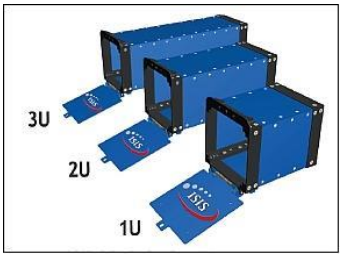
World Financial Systems, Inc. wants to procure insurance for the launch to cover an unexpected failure. Insurance companies, such as Lloyd's of London, have established insurance rates based on the success rate of each launch vehicle. Well established vehicles (vehicles with at least 12 consecutive launch successes) are considered Low Risk and their rate is 5% of the total launch service price. Vehicles with 5 to 11 consecutive successes are considered Medium Risk and the rate is 15% of the total launch cost. Vehicles with less than 5 consecutive successes are not considered reliable and are High Risk. Their rate is 30% of the total launch price. For example: if the total launch costs are $100,000,000 and the team selects a launch vehicle with Medium Risk, the Launch Insurance would cost $15,000,000. NOTE: Revenue paid by secondary satellites (See below) is not included in Insurance Cost calculations.

Secondary Satellites:

If the rocket has excess lift, the cost of the launch can be lowered by sharing the launch with additional satellites. These "Secondary" satellites would pay a share of the total mission cost, thus decreasing the amount **World Financial Systems, Inc.** must pay. Due to the priority of your mission and its importance to **World Financial Systems, Inc.**, only small CubeSats will be considered to share the mission.



A **CubeSat** (U-class spacecraft) is a type of miniaturized satellite for space research that is made up of multiples of 10×10×11.35 cm cubic units (1U) and has a mass of no more than 1 kilogram per 1U unit. CubeSats sometimes use commercial off-the-shelf components for its electronics and structure. CubeSats fit into the excess space on the launch vehicle's upper stage and do not affect the volume available for the **TICKER 2** satellite. They are "ejected" from the rockets using canisters like the ones shown to the left. These canisters can range from a single 1U dispenser, all the way up to a 48U canister. Any size CubeSat can fit into any size canister as long as there is room for it. For example, a 6U CubeSat canister can hold one 6U CubeSat, or two 3U CubeSats, or six 1U CubeSats.



Launch Vehicle Options:

Rocinante II

TICKER was launched on a *Rocinante* rocket built by the Fantastic Voyage Launch Systems Company of Altus, Texas. However, the weight of **TICKER 2** exceeds the capability of the standard *Rocinante* launch vehicle. Therefore, Fantastic Voyage proposes using their new *Rocinante II* to launch **TICKER 2**. This vehicle has been successfully launched only five times and is considered by Lloyd's as medium risk. Fantastic Voyage is offering the rocket at a discounted rate if it is selected for the mission. It can be launched from both Vandenberg AFB and Cape Canaveral AFS. It was used by two other commercial imaging satellite companies. The *Rocinante II* performance chart for missions launched from Cape Canaveral AFS is located on the next page. See Appendix II on how to read the chart. The cost to ship **TICKER 2** from **EXPANSE SPACE SYSTEMS'** Ceres factory to the launch site is $2,250,000.

***Rocinante II* Launch Vehicle**	**Value**
Standard Launch Cost	$75,000,000
Number of Launches Consecutive Successes	5 5
Launch Site	Cape Canaveral AFS, FL, USA
Satellite Volume	4.5m Diameter x 6.3m Height
Payload Attach Fitting	80 kg
Availability	March 1, 2022
Environments Max Axial Load: Max Lateral Load: Max Shock Level Acoustic Level:	 5.5 g's 1.5 g's 3200 g 139.5 dB

The *Rocinante II* Shock Load can be reduced by purchasing a Shock Attenuation Kit, which will decrease the strength of the shock by 50%. The kit would be placed between the **TICKER 2** and the PAF. The Shock Attenuation Kit is 10 cm tall, weighs 10 kg and costs $500,000. Acoustic blankets can be installed to reduce the Acoustic Load by 5 Db. The blankets cost $275,000 to install and weigh 25 kg.

Rocinante II will launch **TICKER 2** from Cape Canaveral AFB, Florida. It is one of America's East Coast launch sites with the mission of placing satellites into low Inclination orbits. It is located next to the Kennedy Space Center. Weather at the site is moderate with occasional afternoon thunderstorms drifting in from the Atlantic Ocean. Launch operations are overseen by the 45th Space Wing which is responsible for ensuring that all operations are conducted safely.

The rocket can accommodate up to two of its standard 24U CubeSat canisters. Each canister costs $1,000,000 and weighs 35 kg.

Rocinante II Performance – Cape Canaveral AFS Launches

Circular Orbits

Spacecraft Altitude in Kilometers	28.5°	40°	50°	57°
2,000	1,887	1,367	867	417
1,900	1,986	1,466	966	516
1,800	2,086	1,566	1,066	616
1,700	2,188	1,668	1,168	718
1,600	2,292	1,772	1,272	822
1,500	2,397	1,877	1,377	927
1,400	2,504	1,984	1,484	1,034
1,300	2,612	2,092	1,592	1,142
1,200	2,721	2,201	1,701	1,251
1,100	2,831	2,311	1,811	1,361
1,000	2,890	2,370	1,870	1,420
900	2,946	2,426	1,926	1,476
800	3,001	2,481	1,981	1,531
700	3,053	2,533	2,033	1,583
600	3,103	2,583	2,083	1,633
500	3,148	2,628	2,128	1,678
400	3,193	2,673	2,173	1,723
300	3,238	2,718	2,218	1,768
200	3,283	2,763	2,263	1,788

Spacecraft Mass in Kilograms

Fēi xīng

Fēi xīng (Flying Star) is an expendable launch system operated by the People's Republic of China. This vehicle is built by the China Academy of Launch Vehicle Technology (CALT), and its first launch occurred on October 12, 2005. It is a two-stage launch vehicle with storable propellants, consisting of Nitrogen Tetroxide and Unsymmetrical Dimethylhydrazine. On August 18, 2007, a *Fēi xīng* failed during the launch of a CALT research satellite, but its past 12 launches have been completely successful. This is the largest launch vehicle available to support the **TICKER 2** satellite. It is considered low risk. The launch vehicle performance chart for missions launched from Jiuquan Satellite Launch Center is located on the next page. The cost to ship **TICKER 2** from ***EXPANSE SPACE SYSTEMS'*** Ceres factory to the launch site in China is $7,750,000.

***Fēi xīng* Launch Vehicle**	**Value**
Standard Launch Cost	$85,000,000
Number of Launches Consecutive Successes	16 12
Launch Site	Jiuquan Satellite Launch Center, China
Satellite Volume	3.5m Diameter x 6.7m Height
Payload Attach Fitting	90 kg
Availability	October 1, 2021
Environments Max Axial Load: Max Lateral Load: Max Shock Level Acoustic Level:	 5 g's 1.4 g's 4100 g 135.4 dB

The *Fēi xīng* Shock Load can be reduced using a Shock Attenuation Kit which will lower the shock impacting the satellite by 67%. The kit is 15 cm tall, weighs 10 kg and costs $200,000. Acoustic blankets installed in the Payload Fairing can reduce the Acoustic Load by 8 Db. The blankets cost $345,000 to install and weigh 30 kg.

Fēi xīng Performance – Jiuquan Satellite Launch Center Launches Circular Orbits

Spacecraft Altitude in Kilometers	25°	35°	45°	55°	62°
2400	1200	1159	1118	1077	1036
2250	1241	1193	1144	1096	1048
2100	1289	1233	1176	1119	1062
1950	1346	1279	1213	1146	1079
1800	1413	1335	1256	1177	1098
1650	1492	1399	1307	1214	1121
1500	1574	1465	1356	1247	1138
1350	1739	1611	1483	1355	1226
1200	2069	1918	1767	1616	1465
950	2508	2331	2153	1976	1798
800	3094	2885	2677	2468	2259
650	3563	3317	3072	2826	2580
500	3938	3649	3360	3071	2782
350	4238	3898	3558	3218	2878
200	4478	4078	3678	3278	2878

Spacecraft Mass in Kilograms

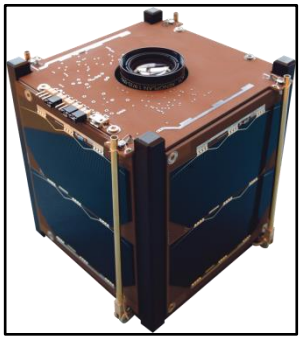
CALT will be launching **TICKER 2** from its launch facility at the Jiuquan Satellite Launch Center (JSLC). It is located in the Gobi Desert, Inner Mongolia, Gansu Province, northwestern China. More Chinese launches have occurred at Jiuquan than anywhere else. It is the first launch site in China. It is mainly used for LEO launch missions and MEO launch missions using the LM-2C, LM-2D and LM-4 Series launch vehicles. It is also used for China's manned space missions.

The rocket can accommodate up to six of its standard 6U CubeSat canisters. Each canister costs $500,000 and weighs 18 kg.

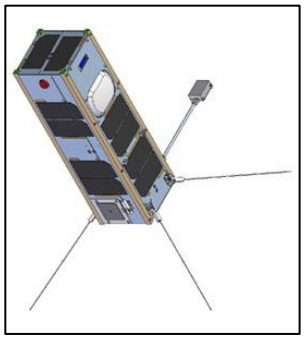
Secondary Payload Availability

Available Secondary Payloads and their launch payments are listed below:

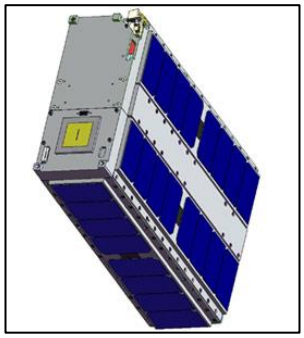
Secondary	Willing to Pay	Availability
1U CubeSat	$100,000	▪ 3 satellites: Need 500 km to 800 km orbit ▪ 6 satellites: Need 800 km to 1,500 km orbit
3U CubeSat	$320,000	▪ 7 satellites: Need 400 km to 600 km orbit ▪ 6 satellites: Can use an 800 km or higher orbit
6U CubeSat	$650,000	▪ 2 satellites: Need 500 km to 1,700 km orbit ▪ 3 satellites: Can use an 800 km or higher orbit



1U CubeSat



3U CubeSat



6U CubeSat

SUMMARY:

World Financial Systems, Inc. is planning to improve its stock market information distribution system. Let's get them the least expensive launch we can. Good luck!

Team Data Presentation

At the end of the practice period, each team should have developed the following information in electronic format for the for the **launch vehicle chosen**:

a. Launch Vehicle

b. Launch Site

c. Secondaries Planned (CubeSats) (if any)
   Note: List Number of CubeSats Deployed

d. Launch Vehicle Options (CubeSat Canisters, etc.)

e. Total Payload Weight (Include Secondaries and All Options)

Note: Use this file to add up the total cost.

An example of this document is shown in Appendix I.

A blank template of this document is available (STLX Sample #4 Solution.xlsx).

StellarXplorers Sample Exercise # 4 Scoring

Scores in this Sample Exercise are based on the total launch cost of the **TICKER 2** Satellite.

Launch Service Cost

Teams will be evaluated on the total cost for the complete launch service required to launch the satellite into orbit. This cost will be subtracted from the launch budget of $175,000,000 to determine the final score. For example, if your total launch cost for the launch service is $96,355,000 for the launch, the total score would be $175,000,000 minus $96,355,000 divided by $1,000,000 or 175.000 – 96.355 = 78.645.

If the launch vehicle causes the satellite to experience loads (Axial, Lateral, Shock or Acoustic) higher than those for which it was tested, the team will be assessed a **50%** penalty.

Teams will lose points if they allow the payload [Satellite, Secondaries, & Other Equipment] to exceed the launch vehicle's maximum satellite launch weight. For each 0.2 kilogram over the maximum allowable launch weight, the team will lose **1** point.

Final Score

The team's final score will be based on the total number of points accumulated from the resultant cost of their launch vehicle choice.

Appendix I

Sample Scenario # 4

Launch Vehicle Selection

Team: STLX0X-0123

Organization: Main Street High School

Satellite: **TICKER 2**

a. Launch Vehicle: Rocinante II

Enter One of the Following: Rocinante II or Fēi xīng

b. Launch Site: Cape Canaveral

Enter One of the Following: Cape Canaveral or Jiuquan

c. Launch Vehicle Options:

	Yes or No
Install Shock Attenuation Kit?	Yes
Install Acoustic Blankets?	No

	Number
Number of 6U Canisters:	0
Number of 24U Canisters:	1

d. Secondaries (CubeSats) (if any):

	Number
1U:	12
3U:	2
6U:	1

e. Total Payload Weight (kg): 1785 kg

Include Secondaries and All Options

Appendix II

StellarXplorers

Sample Exercise #4

How to Use the Launch Vehicle Performance Charts

Spacecraft Altitude in Kilometers	28°	30°	40°	50°	60°
200	6620	6500	5900	5300	4700
600	6488	6370	5782	5194	4606
1,000	6358	6243	5666	5090	4514
1,400	6231	6118	5553	4988	4424
1,800	6106	5995	5442	4889	4335
2,200	5984	5875	**5333**	4791	4248
2,600	5864	5758	5226	4695	4163
3,000	5747	5643	5122	4601	4080
3,400	5287	5191	4712	4233	3754
3,800	4864	4776	4335	3894	3453
4,200	4475	4394	3988	3583	3177
4,600	4117	4042	3669	3296	2923
5,000	3788	3719	3376	3032	2689
5,400	3485	3422	3106	2790	2474
5,800	3206	3148	2857	2567	2276

Spacecraft Mass in Kilograms

First, find the satellite's altitude along the Vertical Axis (Spacecraft Altitude in Kilometers) of the chart. Then, move horizontally from that spot on the Axis. Look for the Inclination along the top of the chart. The intersection of the horizontal row and the vertical column will determine the maximum mass for that Circular Orbit.

Using the Launch Vehicle Performance Chart above, we see that this rocket can launch a satellite into a 2,200 km Circular Orbit with an Inclination of 40º that weights 5,333 kg.

If the value you need is between two values on the chart, then "interpolate" to find your value. For example, 2,000 km is 50% of the way between 1,800 km & 2,200 km on the chart. Therefore, at an Inclination of 40º the value you need is 50% of the way between 5,442 kg & 5,333 kg = 5,387.5 kg.

Likewise, for an Inclination of 42º, it is 20% of the way between 40º & 50º. So, the value is 20% of the way between 5,333 kg & 4,791 kg = 4,899.4 kg. To calculate do this:

1. Subtract 4,791 from 5,333 = 542
2. Take 20% of 542 = 108.4
3. Add 108.4 to 4,791 = 4,899.4