February 12, 2018.
Physics seminar.
>>Dr. Garrison: All right there's a sign-up sheet floating around. Hopefully you got a chance to, students taking the 4372 class, hand in your papers from last week and I did hand them back to you. So I want to introduce our speaker today. I think everybody saw the announcement this is an interesting topic about parts of re-usable spacecraft. One of the reasons we invited Wes Kelly today is we bandage talking for a while about internships with UHCL students. This is one motivation you get a chance to hear more about what they are doing and if this is something you might want to join in and become part of, then you have people to talk to right now.

Quickly his bio. Wes Kelly and associates founded Triton Systems to develop easier systems and for simple and commercial space projects. Since the 70s he participated in design programs for spacecraft local and across the country. Sometimes examining astro physical as well. He obtained his bachelor's from University of Michigan and in arrow astro from University of Washington. Written over 20 publications and contributed to articles on aerospace and astronomy for the local AIAA providers newsletter. With that I'll turn it to wes.

>>Dr. Kelly: Thank you Dr. Garrison. So I'm happy to be here tonight and also happy to say some of our colleagues are here as well to join us tonight from the (indiscernible) with

Mr. Ricky Smith, our test pilot and 70 Christopher Vice President of the organization. Both active on issues and -- one of the interns at Rice and jet propulsion I'll tell you about later.

KATE (Writer): (Having a hard time hearing, audio very muffled)

>>Dr. Kelly: Going back to the abstract historically the news launch systems that had their (indiscernible) go in and out, there have been variations of approaches and one of the prominent forms is to have the re-usable like the shuttle and this case wants to define craft and rocket (indiscernible) but this is not copied very often especially when it come to horizontal take off and landing. When you fly through the immediate trajectory and

the aircraft in an airfield somewhere. We have within examining this approach for a number of years and I'll explain why. But the concept is to start with the size of the gulf stream three. My colleagues have a lot of experience with this. Depends on what airfield you have available and hallow.
Several applications should be promising, most immediate is the deployment of small satellites. I don't have to tell you about that, seems like everybody at the university is trying to figure out how the to get it into orbit.
So as our design is ensured we are looking at the flight design not only the trajectory and some of the material issues the aerodynamics and electronics. I'll give you

some perspective on this besides what you might read on the newspaper and a summary report.
Back if 2007 I was at a conference on the west coast NAII, this is a national organization for aerospace engineering. This convention had a few thousand people there and the chairman or the consulting organization, the aerospace corporations gave a key note address. The I gave a -- was supposed to follow somebody else. The only thing I remember is he's the guy that (indiscernible) (inaudible). Everybody else got out. Room. He was talking about future direction of aerospace out to be in this country. Saying well, you have to choose a middle path. Or in this case we had a path to the right.

And previously we had a lot expendable launch (indiscernible) and then some of the plans looking at re-usable launch vehicles. The best approach he found would be partially re-usable. That's what I'm here to talk about. But there was a catch. The idea was the vehicle was supposed to take off vertically. I said he no, and for many years after, because this seems to be more interest in take off and landing. Now, horizontal or partially re-usable vehicles have been around for a number of years. This is an old textbook I found somewhere that was published back in 1960. Most of these studies are the vertical launch as indicated to the left. Then some discussion about taking off horizontally and obviously it was wrong. But I have a question for you: If you go to a conference and several (indiscernible), how many of you arrive in vertical take off and landing. You got to a conference out of town and horizontal take off. I expect quite a few but basically because we have devices, the 737 here does quite well cruising along and subsonic speeds, 35,000 feet and economic. Planning for partially re-usable launch vehicles, their components exist. Wings. If you look to the right here this was the concept of electric rocket boosters with wings. The idea was to take off vertically (inaudible, OFF MIC) Back in 1990 but it didn't happen. But the launch system -- liftoff to make it work. We were

representing this idea in the year 2,000 or so, we used a drawing like this. This is altitude over here and a vehicle taking off and flying under TURBO FAN propulsion and getS up to CRUISING ALTITUDE OF A 737 AND LIGhts its rocket. The rocket coasts and then this is the upper stage and comes back down to the horizontal landing.
What's interesting about this, at the time it was AGAINST CONCEPTS FOR small satellites. IT might cost $20,000. If you had a thousand pound satellite going up on a Pegasus rocket, might be 1,000 pounds, $20 million or so. So whether you can beat that price or not there's still problems.
So here's what our concept looks like. You may have seen the video before I started

talking that went through the sequence.

(AUDIO MUFFLED)

>>Dr. Kelly: We gave a presentation for horizons. If you notice in the lower point there's a lot of sketches of the trajectory and how it varies and I'll get into that more in a moment.

The upper stage flight is illustrated by the darkening sky and the upper stage goes to satellite. We have a couple of organizations, maybe three or four that are interested in flying with us (inaudible).

But I'll pull the brakes for a moment. Is this for real? Is this something like a unicorn? Or is there something there?

Well, let's look at some other vehicles that have horizontal profiles and trying to go off into space. Back when I was a kid in the 60s, late 50s, the X15 was released from a B52, about 35 to 40,000 feet. Fly up to about 6,000 feet per second and what's indicated up here. They had another flight path they fly at 70,000 feet at the same speed. They would heat up at that speed. The higher the trajectory it's more (inaudible, PERSON COUGHING). They did this with three aircraft in a period of several years and there were about 200 flights. So operationally it's a can do. So here's a vehicle that never flew. Like the little engine that could. A lot of data associated with this. Just short of flying and we have some members FLYING and we -- you see that feature right there. The red, there's a roller coaster ride and I believe that's the larger wing

span. The delta wings caused it to glide farther.
Other hardware we might see the Shuttle Endeavor flew into Houston in 2012. It was nested on top of the 747. It was released at 20,000 feet for approach and landing tests and then it was carried across the country to various launch sites. This is not the shuttle but a vehicle like it. It actually took off. It was the version of the same thing on display in Germany. A friend of mine sent it as a note. And it had four tush bow jets that flew up to maybe 20,000 feet and did it's approach test the old fashioned way.
There's another point in favor of take-off and landing. If you are going to do this it has to be for a reason (inaudible, OFF MIC). Normal take off with

wings everything, jet engines, it makes sense if it satisfies a certain criteria. Rocket engines on board have high performance and impact economical but expensive to manufacture, you want to get them back. There's a lot of reasons why space flight is expensive, all of that hardware in the Atlantic Ocean. And the criteria for looking at the effectiveness of a rocket engine in terms of this so-called rocket equation which is in red up here. The first stage and start and so-called specific impulse I with the subscript SP. As that increases the mass DIFFERENCE INCREASES and you have more payload left. You get more lift when you are going back thanks to the jet engines you get to an altitude more economically because they are effected by the speed it's ten time higher than a chemical rocket.

Also the so-called recurring and nonrecurring costs referred to as RDT and E, there are competitive systems. And missions that are attracted to this for the right size and ergonomics and environment.

And the vehicle is flexible, versatile to go after these projects.

Now these two gentlemen are probably people that are referred to as important people you probably never heard of. I wouldn't if I didn't get into this business at the right time and ended up at the right place. Valentin Petro Glushco and nikolai, they were in the Soviet union and developed rockets. But they had the distinction of building the most remarkable engines of the 20 century. This country for space operations -- they probably had longer lives -- recent times is with the space shuttle main engine burns liquid hydrogen oxygen. It was aerospace than kerosene.

(audio very muffled)

The basic stage system turbines and partially burn propellant oxidizer into the combustion chamber which is higher pressure than the alternative which is called gas generated where that fluid was dumped over the side. So these are high energy systems and the fact they come up with these was probably something difficult to compete in this country but was an opportunity for a reasonable rocket systems.

So here's our answer. And this is a vehicle that we propose to develop here in the Houston, I should say, even more specifically the ellington field. Looking at the X34 image we had earlier you go up and down with that roller coaster, angular cap for the various flights, six or seven Mac and an altitude which is high as the edge of space. I think the trajectory I've been writing is 320,000 lately. The verse tilt features of this vehicle, you can go off any direction, with an airplane you are not a speeding bullet. The up per stages you can carry from the initial tip toes or treading into water and the upper stages. And the capability of the launch site. There's a hurricane in one part of the country, take off with

this vehicle ab land it in an airfield there. And you can do flight TESTS without ignition of the rocket because of the commercial aircraft engines should do the jobs for TO GET YOU UP TO ALTITUDE (inDISCERNIBLE) or you can see the properties of the (INDISCERNIBLE).
So I guess I probably explained most of why we do this. The reasons we just discussed. Market consideration. This is a great time for launch vehicles. Scalability. And if you want to have an alternative to say Space X doing everything in the future like standard oil did for petroleum might be interested in alternative such as a horizontal take off and landing. Although I admit I admire the demonstration done last week.

This is, I'll say these are graphs, there's a corresponds to events in the flight phases. The ignition here. The beam point here. We have areas where you get the rocket engine started.

Now, from the commercial standpoint we have found a summary the so-called Stellar-J elevator presentation. MIT enterprise forum downtown, essentially you try to send up everything that you are trying to do for a potential investor on an elevator ride. This is the world trade tower. The idea is the small satellite user community needs an inexpensive reliable launch system. That can grow with the user. Cultivate capabilities for the future such as rendezvous or return cargo. Maybe those are not the only things but you have to anticipate something. Besides the community both domestic and foreign is large. Small companies want to large satellites and more people are building (inaudible). Civil military offICES have a Need for a satellite. Research institutes, universities and related research such as down the street with planetary science and the organizations associated with that, and potentially University of Houston clear lake. So our approach is a horizontal take off and landing first stage with wings and jet engines. Rocket burn from airline cruise to typical booster rocket staging. As big as an air bus, like a 380, IT'S hard to find a place to land. Payload is (inaudible, AUDIO MUFFLED).

And that would be (inDISCERNIBLE).
So what is the virtue of the rocket engines (inaudible).
(Off mic). I'll give you the answer. It takes the work out of thing I just mentioned. If you are 40,000 feet closer to your trajectory there's work involved get there. If it's on the left side that indicates there's a (off mic). No work is going into and the energy is something that is flying along the at sphere at 2000 feet there's work involved and less work to get to that orbital station from the flight to the ground.
I'm going to veer off again myself and look at this a little differently than what I was going to continue to do because this is an organization involved in physics. And some

of that is related to research and I often look at emails at the tail end you have professor Garrison send (indiscernible). If we knew what we were doing it wouldn't be called research. We will talk about an episode like that. Most of the talk is about design and analysis. You see what happens when we change this. That's what a lot of this will involve. Finally there's the development phase and people looking at charts and saying let's look at the results and the schedule. And then finally (inaudible). Several years ago working with a subcontractor on a contract with (indiscernible) looking at propulsion systems they were interested in beam energy. I didn't know much about it so I started to check it out. So we were looking at how beamed energy can be used to propel upper stages on rocket systems. And the idea that either you launch on the ground and maybe on an upper stage where you have a beamed energy propulsion system using hydrogen as a fuel and laser beam and microwaves cause us to exit of high energy or you are in orbit and doing this. So we wanted to see if there's anything we can learn about it. We studied the projects. Looked at the geometry. If you get a chance to look at this you might mind it interesting. Basically there's a window where you can get the ground site and see a spacecraft or orbiting satellite coming over the horizon. The question comes down to if you have this for an upper stage can you take advantage of it. So we compared the characteristics of beamed energy which might be higher specific impulse than a chemical engine and saw that trajectory on a finite burn, the dynamics, not just the calculation, but the integration. And various colors indicate which of those we are talking about. 500, 600, 800 seconds is the most efficient. And these are the trajectories down here. Where the Stellar-J comes into the act is if this beam is coming from a ground station on an island or aircraft battleship you have choices you can fly over that site. You can fly out in some direction and go to switch backs. But when you came over that flight where the laser beam was you can aim your trajectory in a way you can get this all as REGION we have been talking about. (AUDIO MUFFLED) Look at the impulse how much weight payload would be left. Also see how many mega watts you have to direct in that direction if you have 100 percent efficiency. Say from 4,000-pound system from the Stellar-J we are talking about a 30-megawatt system on the receiving end. When you look at the system you find there's various ways you can have problems. Now we got to talk to the designing analysis, engineering in other words. And I try to do this in a hierarchal approach, staying at the top of the pyramid for sake of argument and computer tools, some discussion about which ones you use and why. And then the output behavior. And what you would get out that have would be trajectories that would determine how you layout your vehicle. Mass property, aero thermodynamics, control systems, materials, hardware such as wings, jet engines, several protection systems. Beyond that if we have time or interest it would be missions and markets criteria for trades.

This is going to local type of trajectory simulation. That's what you use in the aerospace community. But there's a couple of problems. First is it's directed to minimize the time or fuel expended between two points trying to optimize the trajectory, doesn't tell you about the design or how big the wings are. Just tells you how to use it efficiently. So a whole lot of my experience, not really getting down to the fast tracks of how these are designed. That's important. I want to emphasize that. Ways to which -- jet engines and rocket engines are separate neighborhoods. They hardly talk to each other. If there's a tool like (indiscernible) you won't have a JET engine in there or a simulation of an aircraft. And vice-versa, simulating aircraft they don't have much to tell you about rockets and how to maneuver them. So we have to develop a system of our own. We started a number of years ago and you have inputs, there are kind of succinct but we feed to describe the vehicle we are talking about and change and the data files (inaudible) SO we can tweak them because we run them again and because things we look at, all the things we want to know ABOUT

AND THEN (inDISCERNIBLE). Basically these would result. Trajectories such as this where you would have first stage thrust level, altitude, expendable upper stage, and you keep track of it. And the two stages combined. And then what the weights were delivered into orbit, mass fractions for the up per stages. But the aircraft portion you had to have something trying to lift, drag, thrust and gravity. (inaudible). And others features such as glass. These are some of the principle GLASS (inaudible) the capabilities of the vehicle. First is the time that the burn on the trajectory. Ninety to 135 seconds, you can get so much velocity and altitude at the end of it and that reflects the payload you will have taking orbit.

B is when you come back down what is the end of the (inaudible, OFF MIC). Which one is it suited for. Two things to consider at least. The range, heating and possibly the how many Gs (inaudible). D is what happens when you banking the vehicle when you come back, how much range you get, which airports can you reach or take off from and how much do you have to (inaudible) on that.

Other issues are heating. And dynamic pressure. With the shuttle is talking about 700 pounds per square foot or something of that nature. You will see aircraft here in Houston an air show as they flyby. So we keep track of that as well. And the heating comes back down or going up in terms of square foot per second we figured we have a be sign -- and the scram jets hang around in the atmosphere and they get pretty high.

There's also consideration that where this geometry is, now if you have a vehicle that has a delta wing and vertical tails and various sweeps on these features, the heating is going to be effected by what the sweep angle is and with respect to the angle of the TACK and the wing. It's going to VARY on the geometry, which way it's pointing.

This is an analytical relationship here. Based on formula I don't see on there and can talk about later. But there's contours you can look at the vehicle and see based on the radius of the sweep angle and the atmosphere how much you

you have to integrate it all together AND MAKE DECISIONS. Then the range itself besides the thickness, how much lift does it have. NASA has quite a collection of a slice out of the wing, I guess the projection of the wing going in the Y axis. And it has some influence on how much lift you will generate and the areas on the wing and we take them together and for a finite wing theoretically at the wing and various angles and speeds... This is all great but it does come to an issue that comes up and (INAUDIBLE, off mic). All the people part of the community know how many pounds you can deliver in orbit. They do it based on a configuration and say I can get this much. And you think that's great. Get down to it and how much is my wing going to way on the design and the features and what it will look like inside and how much -- you realize your orders of magnitudes is delta of a couple of pounds. You have to worry about the wing and how it's built. Roughly they take about 10 percent of a vehicle total weight couple of exceptions. The basic components of the wing structurally fall into four categories. Skin, spars RIBS AND (indiscernible). The ribs are lined along the axis. The spars go out along the span. So you call that Y axis. And the strings are lower order magnitude. The first three is the one we concentrate on. In addition to the spars and ribs are they going to have sweep and HAVE GLASS, how do you get the (indiscernible) if you have sweep? So YOU HAVE TO FIGURE OUT what do you do about the SPARS AND THE ribs. (inaudible, AUDIO MUFFLED). As I SAID TO my colleagues AT the GMC community, this thing OFF to the right, THIS DIAGRAM is not a wing. It's KIND OF Stuck in there, but it's a stress and strain diagram based on all of those cantilever beams they are lookING at. Some of cantilever and some are beams connected to other beams. So when we look at modern aircraft it looks like an elaborate mesh. You may have encountered this in statics so did I a number of years ago and forgot about it. Then during a lapse of activity I had to study this all over again and found it fascinating. Basically Young's MODULUS analysis and the slope this diagram for a material. There are materials of interest and besides stress and strain we are worried about what it would be like (inaudible, off miC). How much these lose strength based on alloys and solid temperature. If you have a room temperature strain and a temperature that you know where this effect is or liquid formation like the alloys a boundary, you know don't extrapolate strength beyond that temperature. Working in the industry, one thing that happened is the reorganized more in space (indiscernible). Delta wings problems we saw in the 50s and 60s. Samuel Levy was crucial for delta wings. That one vibrated beam or one that deformed, I guess there's displacement at the end, elasticity. Because they are working together in a system of equations, but the (indiscernible) is that he came up with methods that are amenable to small computers at the time and still can be used today. And the remarkable thing is -- I'll go back. Basically what they did with these models the B58 no matter how you feel about the nuclear war, it's an interesting aircraft because it has delta wings high technology. And these modeling methods were able to predict how it deformed under load. So practically you can do it with a laptop. If you know what you are doing. And he (indiscernible). But in setting up a delta wing there are a number of approaches you can take. Spars going up and fuselage AS WELL and if you (indiscernible) the deformation at the end IS GOING TO GROW IN POWER.

(AUDIO very muffled)

You see an evolution -- here is the B58 I was speaking of. This is a report by colleagues that drew on Levy's work and showed how to predict loads with a matrix method and they got close results to what is seen in (indiscernible). Now, I looked at this diagram and I thought maybe I can rearrange it. Basically they had displacement, slope of the beams, the reach of the spars and the moments and the shears. Let's hold that thought. Here's a F15 that has three or four spars, I guess five or maybe six visible ribs so that might be an indication of a workable system. Here's a space shuttle it's interior wing and we see 11 grids and four spars, four spar system we will be willing to look at. Here's an rearrangement of that system. It's along the diagonal you have a sparse region here so you can treat this and simplify it considerably. A lot of spaces are just simply null. It's encouraging. So if we get a larger system, here we changed it to reactive force at points A and B on the spar. And moments are involved. And Displacements. So you have a system and these smaller matrices and you can start looking at loads and get some sample calculations. Did I get any answers? Well, I used some free algebraic manipulators. I found it difficult and ended up with a lot of algebra. But all the same, we are interested in the sensitivity of the displacement with the temperature conditions. And these are analytical solutions you can obtain. I did a lot of work on this. There's promise to this method.

Some textbooks that are useful for this study, the aircraft dynamics and automatic control, I would like to point this textbook out because it examines a number of aircraft in great detail, their structure, the arrow dynamics. The aerodynamics are useful in this book and rocket propulsion elements as well.

The reason I mention this what we are trying to do with the Stellar-J is create the same matrices, the same descriptions of these ten, 15, 20 aircraft examples. If you go to NASA (indiscernible) they have 100 aircraft like this, they will tell you about the spars, cross sections of the spars. But they add up to a system of equations that are characterized by all the design decisions that you make, and the stability of the aircraft and various stages of flight are indicate the by these columns. So we are doing the same thing. Maybe a dozen phases with the Stellar-J looking at what it's doing on different structures. Geometrical inertial parameters. Longitudinal dimensional derivatives. Lateral dimensional derivatives. What happens when you deflect the elevon, the aileron and the rudder when you have to switch them? Second-order differential equations you are dealing with and solutions and the response and frequency and the damping. You have in this case the simple analysis procedures that are used in aerospace. You have four solutions for each of these systems, lateral and longitudinal. Some maybe oscillatory and some not for the -- longitudinal and (indiscernible) and oscillations.

To get to the point where the vehicle is well based we are trying to get the components of the vehicle modulator. When we discover we have a problem we can trade them out. Or search in the right direction.

Recently did a lot of work for us including the simulation we had at the beginning showing the phases of flight. Now illustrated the effecters it's aerospace to look in the back. The rudders they can use --

they can be used for turning (indiscernible). They are still not sure whether they are going to use rudders, it maybe two complicated. Early stage we are looking how they can all be tied together including thrusters because we are moving to the edge of space. In doing all this trying to keep track of all the mass properties and then during the various phases of flight we have principles to collect this information, how much the vehicle weighs, where the mass is distributed.

Whether it has the upper stage and to keep track. There's a certain size booster we maybe flying. And then the first stage (inaudible). If it advantageous than pumping it later as indicated in this diagram.

Here's the larger scale. You

can see the layout of sub systems. And some of the choices you are examining for the ribs and spars and this case an introductory case we have a sweep on the spars and we will look at the perpendicular cases as well. To the left is a blow up of the airfoil contours for the CA (inaudible) not to scale XY. We have two stages RATHER THAN ONE STAGE. Stages more efficient in payload and acceleration. And also we get a liquid booster instead of solid. Here's an attempt to keep track of all the mass property. The programs try to talk to each other on solutions. Here's an indication we can be doing ferry flights from say from Houston to KFC and carry the booster on top of the vehicle

and maybe have a carry load to -- increase the lift to drag ratio by decreasing THE DRAG. There's an indication of how the reaction control system might work. I did this 20 years ago and how it works. You can see it with the tiny red lights (INAUDIBLE, off mic). The vehicles that separate, this point we have an active WAY TO move the Stellar-J from the stage when they are coasting the upper stage. But to get away from the upper stage you have to (indiscernible). And after that while coasting back to the atmosphere you need some control. So you have control laws you have to use and the up per left it indicates which way the thrusters point.
Then a few more minutes to talk about aerodynamics. Despite

it's high -- low lift drag ratio the shuttle orbiter has something to tell us about the Stellar-J.
It's CG was center of gravity getting all of this mass concentrated so the center gravity was BOXED. IT'S located two-thirds in the back of the vehicle. Various flights to keep track of (INDISCERIBLE) not a reference for a system of 1140 inches downstream on an X axis. And then had some Z displacement as well. I won't get into that too much. We tried to do something similar and replace our CG, I should back off on that. That would be the aerodynamic center for the vehicle.
There's root chord center and you can see the length of the tip and root chord. The

reference area of the vehicle is defined from the orbiter and Stellar-J at the air of these trapezoid features. Despite this, if you look at the orbiter the wings it comes down to that's driving the referenced area. The calculations of the lifted generated with various things intact based on the finite winning these are calculations. This is where I wanted to draw your attention. The aerodynamic data, the base area. I'm a little suspicion about the area of the six square feet. I would say the Stellar-J is with or without the upper stage. But that gives us an indication of how to calibrate our vehicle in terms of aerodynamics. And the (INDISCERNible) is supplied in a 1,000 page document.

To wrap up with jet engines trades, we have determined we have three at least three engines we are looking at. From the Rolls-Royce family. I think it's a 550 (indiscernible). But this is the oldest, midway and each has higher thrust. Now, it's a question of keeping your eye on the doughnut and not the hole. The thrust is high altitude. As much potential energy as we can we want. So we want to know how fast we are flying with altitude and how much thrust we can obtain. So there's parameters associated with the jet engines and there might be enough to be manufactured. (indiscernible) is HERE with us tonight, but she is STUDYING ON EXAMS AND SHE working on this particular intern program. We made some progress over the last month or so. Besides the simple issue of how much thrust are we going to get, the methods we have been using is analytical hierarchy in the past. Even starting this program look at what way to extend our efforts as far as what payload to go after and what do we think is the best. We sort of have several parameters we have looked at. And we have to grade them and decide which one is the 34069, best choice. Well I can't tell you what the best choice is right now for jet stream engines. And maybe more will qualify as well. Maybe it makes sense to have four engines instead of two. But engines over the decades have changed and we have to have a way of evaluating and not make a quick decision by simply pulling them out of a hat.

So far without taking into account certain elements of the engine cycle we have got where drag and altitude crosses the line. 6,000 pounds, 5,000 pounds are indicated by red and orange and as we have the engines modeled thus far, basically what they are doing is extrapolating from the static thrust in the ground taking into account the fact there's a turbo jet and a turbo fan with a bypass ratio and so if you can calculate what the thrust is based on your assumptions about those two features, based on temperature and exhaust and how much exhaust there is, we can make an extrapolation and say how much thrust we get in altitude based on the (indiscernible)

DENSITY AND atmosphere. Then we have to go into more detail for stagnation and flow of the air and the corresponding temperature and the stations (indiscernible). So we expect these answers to change. I think actually they might go higher. But we will see. Is he this is just another look at a tracing from the standpoint you are doing this with a car. You have four or five criteria and we identified seven. Capability to high altitude (indiscernible) reduce Delta V from the upper stage, weight ever the engine. How much fuel is consumed to get to where you want to go. And the issue of range. After the satellite is deployed when you are going back the game changed. You are not looking for altitude you are looking for range and you will take anything you can get. So you have to balance what you can get. The ends conditions versus initial conditions. The cost per unit. Do you want to bankrupt and the liability. And restart. Something we had long conversation with. Mr. Smith and Mr. Christopher. Some of the investments are interested in that as well. Is this going to crash on return some of course the operating right which is effected by the liability.

Well, I think I'm done for now. I'm going to skip over this document search and can include our talk and turn it over to the audience and whatever transpires from here. I thank you for your attention and enjoyed having this opportunity to speak with you.

(APPLAUSE).

>>Dr. Garrison: Questions?
>> (inaudible) have you considered (inaudible).
>>Dr. Kelly: (Off mic) (inaudible).
>> Horizontal take off and landing, have you considered, I know (inaudible) once you get to the.
(INAUDIBLE, Mic too far away).
>>Dr. Kelly: You have positives and negatives (inaudible).
>> (inaudible).
>>Dr. Kelly: (inaudible) at this stage you go through a commercial space (indiscernible), they are pretty detailed. (inaudible) after a number of years you can advance the (indiscernible).
>> At some point during the supersonic, even though the engines are near the back of the plane if there's still a

problem with the shock wave
would you be -- (inaudible).
Would that --
>>Dr. Kelly: The
(indiscernible) would
transition. How much shielding
or diversion (indiscernible)
we need on an after that.
Coming back out we have
20-degree angle tack, you can't
see that. The advantage of
high altitude the density and
pressures are going to
(indiscernible) and the net
portion of the trajectory is
only several hundred seconds
all together with the flight.
So the major problem maybe
solvent. I refer to the least
amount of metal as possible.
>> A lot more friction (PH).
>>Dr. Kelly: And then finding
a turbo jet with
(indiscernible) turbo jet, I
know they are out there, but

then you got the specific shield consumption higher it might be three or four times as high, so then the (indiscernible) you have to carry to the point to -- has to be evaluated. Just like with the jet engines trade at the back. You can look at it but... then the drag after you transonic the drag goes up considerably and wonder if it's worth is it with a lighter rocket.
>> Have you considered any (inaudible).
>>Dr. Kelly: Yes. We have tried a -- we talked about (indiscernible) and a couple directors had conversations with them, and (indiscernible)...
(microphone muffled).
Anybody else?
>> (inaudible).

>>Dr. Kelly: The upper stage. Let me see if I can find this. See right up here, it would be under that. That's a payload carrier, I guess in the animation we had earlier the (indiscernible) might drop off earlier than indicated because we are high altitude, generally my ballistic launch vehicle days some of them drop off 200,000 feet halfway to orbit as far as the velocity is concerned. And longer you carry the more penalty it entails. Maybe get a clearer picture from the schematics -- I want to indicate that structural and the concerns -- there we go. So that would be two spherical stages rocket and nozzle and right under here would be an engine. You could crank up the...

>> (inaudible).

>>Dr. Kelly: That's Ellington
there I hope in the near future
if we went to 135 seconds it
would be sometime after
185,000 feet. The lowest I
looked at 185,000 feet.
>> During separation
(inaudible).
>>Dr. Kelly: There are
clusters on the main stage that
are located on the vehicle. So
the upper stage
(indiscernible). Well, this is
kind of new territory in a way
because the control systems
on -- mostly (inaudible) thrust
directions (indiscernible).
Solid rocket (inaudible) (off
mic).
>> (inaudible).
>>Dr. Kelly: Dynamic pressure
the atomic, velocity, density,
whether the pressure is per
square foot. It's on the space
shuttle the opportunity to

(indiscernible) and it's either 25 or 75 (indiscernible). These are heavy systems and might be higher.
>> General stability issue the only issue to consider (inaudible) that's why you need the thrusters (inaudible).
>> (inaudible).
>>Dr. Kelly: (inaudible) over here there was a system I used not exactly AHB but trying to identify what the markets were and grading the markets in terms of criteria. One of those final slides was about that. But one of the things was every year you do that you need to (inaudible).
The upper end of this is 350 tons, you can have three of the (indiscernible) three engines on the tail width, just two, and you have the effect of something similar to the

(indiscernible).
(Microphone muffled).
>>Dr. Kelly: (inaudible).
That would be long-term issues.
Running out of things to say.
(LAUGHTER).
>>Dr. Garrison: Any other questions?
>> On the design how does that compare to the (inaudible)...
>>Dr. Kelly: Well, to address that other than to the jet engines on the SR71 multi cycled, they had a limited (indiscernible) capability and then their design and other features were designed top Mac three. This vehicle is not designed for cruising opportunity. We hope (indiscernible). And high altitude so there won't be too many disturbances. The engines on the back, to address that. There would be a tendency or

for the center of mass so it won't flop all over the place. But that's our side. Our new side with the (indiscernible) it's designed at a turtle jet to act like a Ram jet -- three times the speed of sound. The temperature on the skin is probably around 500 or 700-degrees far height maybe. (inaudible). (Fahrenheit).

>> Any other questions? Let's thank our speaker?

(APPLAUSE).

>>Dr. Garrison: We want to invite everyone back next week.

(End of seminar).

(No audio.)