RING WORLD

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SETUP

- Set sky with Gemini high in sky
- Cue DVD & slides
- Make sure clipboards have pencils
- Setup Saturn dot projector
- Path Option cards ready

SCRIPT

Cove lights down. Fade daylight off as stars come on. Saturn is in Gemini.

INTRODUCTION

Welcome to the _____ Planetarium. This show is called "Ring World" – what some call the jewel of the Solar System. ***Can you guess what planet I'm talking about? [Saturn!]*** Though people have known of and gazed at Saturn since ancient times, there is still much we do not know. This show will illuminate some of the mystery and wonder that Saturn has held over the ages.

We will also talk about the next phase in our quest for knowledge about this ringed world! For the citizens of Earth have sent an ambassador to this world. {Its name is Cassini-Huygens} (pronounced "HOU-gens"). {On October 15, 1997, it sailed out from the port of Earth on a seven year, two billion-mile odyssey to the outer solar system.}

VIDEO: Cassini emerges

{The size of a school bus with a total weight of over 12,000 pounds, and an array of 18 packages of scientific instruments, Cassini-Huygens represents the combined effort of scientists and engineers in 18 countries, and is one of the largest, heaviest, and most sophisticated interplanetary spacecraft ever launched.}

WHERE WILL SATURN BE?

Observers have known Saturn since ancient times. ***But how can you find Saturn in the sky? [Take any answers.]***

{To ancient sky watchers, Saturn was one of five so-called "wanderers", or "planets" that, night after night…month after month, slowly danced among the stars…as if they were "the gods themselves".}

For example, here is Saturn in our planetarium sky now[1]. ***[Point to Saturn.]*** It wanders among the stars through the heavens along an imaginary line called the ecliptic. ***[Activate ecliptic.]*** This is where you can find, not just Saturn, but all the planets, the Moon, and the Sun. But you will not always find Saturn here. Over time, Saturn will wander – and the question is, where to?

Deactivate ecliptic. Pass out Saturn Tracking Sheet, and invite audience to take a clipboard and pencil.

This sheet shows just a portion of the sky – an area dominated by the constellation Gemini. There are different sizes in the dots you can see. Can anyone guess what the difference is? ***[Bigger dots for brighter stars.]*** Yes, and the two brightest stars are called Pollux and Castor – the mythical twins famous in Greek stories – and can be found here. ***[Point to Castor and Pollux.]*** Now, looking at how the stars of Gemini are oriented on your sheets and how the stars are oriented in our sky, ***make a mark to show the position of Saturn now.*** It will be that bright star-like object that is *not* shown on your charts.

Help the audience by describing that Saturn is right next to "this" star, or just below "that" star. You may want to go around and check with a few people to make sure they have the right idea.

Now we are going to skip ahead a couple of months into the future. ***Where do you think we will find Saturn? By show of hands, who thinks Saturn will be in the same spot? To the right (along the ecliptic)? To the left (along the ecliptic)?*** Remember that we should find it somewhere along the ecliptic.

Show the ecliptic again briefly (if necessary). Advance Saturn to the next position.

It has now been two months. ***Can you find Saturn? [Invite someone to point to Saturn.]*** Right. Is that where you predicted it to be? ***Mark Saturn's new position on your sheets. Where do you think Saturn will be***

[1] This initial position we used for Saturn is March 7, 2004 – when Saturn was in prograde motion. The subsequent positions used are approximately two months apart, and were chosen to occur before Saturn began its retrograde motion.

two months from now? In your minds, make a prediction – you can share your prediction with your neighbor if you like.

Advance Saturn to the next position.

Where is Saturn now? [Invite someone to point to Saturn.] We are going to look for Saturn one more time. Make a prediction again, and let's get ready to skip ahead two more months.

Advance Saturn to final position.

Who can find Saturn now? [Invite someone to point to Saturn.] Now, we have seen Saturn move through this much ***[point to the span of Gemini]*** in about six months. Remember that Cassini has been traveling for seven *years*. Saturn itself has actually traveled through four constellations in our skies during that time – about one-quarter of its own orbit around the Sun.

Have audience replace pencils and clipboards.

SATURN THROUGH THE AGES

{In the early 17th century, the Italian astronomer, Galileo Galilei, first pointed a telescope toward the heavens and, in so doing, began to transform these "mystical lights" into other worlds to explore.}

SIDE: Phases of Venus

{Galileo's telescopes revealed that Venus went through a series of phases as does our moon.}

TOP: Moons of Jupiter

{They also showed Jupiter as a sharp disk with four satellites of its own traveling about it. But Saturn, the most distant and slowest moving planet then known, proved even more intriguing.}

TOP: "Triple" planet

{At times, it appeared to be nothing less than a "triple planet", as if, Galileo wrote, this old man of the heavens needed the assistance of two servants in his slow walk around the sky.}

{Yet, several years later …}

TOP: "Single" planet

{…what had appeared to be three objects in Galileo's telescope, became only one – the servants having apparently abandoned their master.}

TOP: Various sketches of Saturn

In fact, here are some sketches of Saturn made by Galileo and others. ***How would you describe the features you see here? [Take any answers.]*** Some referred to them as "ears" or "handles" or even "arms".

{In 1659, the Dutch astronomer, Christian Huygens, used a more sophisticated telescope to solve the mystery reported by Galileo …}

TOP: Saturn sketch w/ ring

{and revealed that Saturn's triple appearance was actually due to a beautiful ring that somehow encircled the planet – a ring so thin…}

TOP: Saturn at different tilts

{…that when occasionally viewed edge-on, virtually disappeared as seen from the vast distance of Earth.}

TOP: Cassini division

{In 1675, the French-Italian astronomer Jean Dominique Cassini used still better optics to discover a large gap between the rings – a "division" which bears his name to this day.}

{As the centuries passed, telescopes grew ever larger and more sophisticated. And, with them, astronomers steadily discovered more details in Saturn's atmosphere and rings…and an ever increasing number of Saturnian moons.} ***Any idea how many moons Saturn has? [31 official moons[2].]*** Indeed, in recent years astronomers have many new moons previously undetected.

{But the turbulent nature of Earth's atmosphere frequently caused images to ripple and distort and the billion mile gulf between Earth and Saturn still limited how much could be seen and learned.}

So, what do you think is the best way to study Saturn? [To go there!]

[2] As of June 2004.

TOP: Voyager 2

{Between 1979 and 1981, Pioneer 11 and Voyagers I and II became the first spacecraft to reach Saturn. The result was nothing short of an explosion in our knowledge of the ringed giant and its satellites.}

SIDE: Saturn's atmosphere

{Indistinct bands in the planet's atmosphere were transformed into intricate weather systems driven by 1100 mile per hour winds.}

SIDE: Saturn's rings

{Saturn's rings were divided and divided again into hundreds, then thousands of "ringlets". And many of Saturn's satellites instantly grew from mere dots in the best telescopes on Earth into amazingly different worlds.}

{But Pioneer and the Voyagers were but brief visitors in the night speeding past their targets in days or even hours, never to return again.}

TOP: Cassini spacecraft moving through space

{Now, more than 20 years later, thanks to Cassini, we will come to stay and study the domain of this "Ringworld" in unprecedented detail.}

THE PATH TO SATURN

If you were going to go to Saturn, how would you get there? What is the simplest way? [Take any answers.] Well, we have a few options. I have here a few cards that show some possible paths and some considerations to go along with each option. I am going to divide you up in to groups, and I want you – as a group – to decide which path is the best one to take to get Cassini to Saturn.

Distribute one set of cards to each group of three or four. Turn up cove lighting so cards can be read. Give a few minutes for group discussion. Each card has a sample trajectory

path, the energy required, and the time required.

Alright – let's see what you decided on. ***Raise your hand if you and your group chose option 1? Option 2? Option 3? Option 4?***

Count up the votes and have each group explain why they chose each option. The audience should understand the various pros and cons of each option, including (but not limited to) the following:

Option 1: The straight-line path, firing rockets the whole way (to keep us straight – gravity from planets will naturally curve our path). ***This will get us to Saturn quickest, but requires the most energy.***

Option 2: A curved path, with one rocket burst from the Earth, then coasting to Saturn. ***This takes a little longer, but saves energy (by not using rockets the whole way).***

Option 3: Aim for Jupiter first, and use its gravity to boost Cassini towards Saturn. ***This takes longer since we aim for an intermediate target first. However, energy is saved by using Jupiter's gravity to "push" Cassini that last leg to Saturn.***

Option 4: Travel in towards the Sun, then use gravity-assists from planets along the way out to Saturn. ***This takes the longest, and requires traveling away from the target first. However, using four gravity assists saves tremendous amounts of energy.***

Certainly time is a factor in our decision, and as you can see it varies greatly from one scenario to another. ***From your cards, can you tell what***

we need if we want to get to Saturn very quickly? [More energy, or more fuel.] Right, just like if you want to get from Berkeley to LA, the faster you drive (the more energy you use), the faster you'll get there. But if you run out of gas, you need to get more. ***Can you do that in space? [No!]*** We have to carry *all* of our fuel with us from the *beginning*. However, the more fuel we carry, the heavier our craft is and more difficult it is to get started and to maneuver. And, there is always the issue of cost – more fuel means a more expensive mission.

So, we might have to trade a little time for a little fuel efficiency. ***What can we use to help get us to Saturn that won't require so much fuel? [Gravity from planets!]***

GRAVITY-ASSISTED MANEUVERS

Some of you may have heard of gravity-assisted maneuvers or "gravity-boosts – when you use the gravity of a planet to speed you up or slow you down or even just to change your trajectory. It's often described as a gravitational "sling-shot", where gravity pulls you in towards a planet and then shoots you off at a greater speed than you had before. Well, it's a bit subtler than that.

SIDE: Gravity-assist cartoon

Let's take the example of throwing a baseball at a fast moving train. Imagine this red ball ***[point at slide]*** is your spacecraft, and this train is a planet, like Jupiter. If you throw your ball at the train, it might approach at 30 MPH, while the train is moving at 50 MPH. While you (and the Sun) see the ball moving at 30 MPH, the train sees the ball approaching at 80 MPH. When the train hits it (at 50 MPH), the ball rebounds at that same 80 MPH *plus* the 50 MPH the train is moving at. So, the ball ends up with a final speed of 130 MPH.

The same thing happens with a spacecraft and a planet – except instead of bouncing off the planet, the gravity of the planet deflects the path of the spacecraft and sends it speeding away at a faster speed. The key is that the planet (or the train) is already moving at a great speed, so the spacecraft steals a little bit of that energy for itself. That energy is very small compared the energy of the planet, but is *huge* for the spacecraft. It allows the spacecraft to accelerate enormously using just a tiny bit of fuel.

So the decision of what path to take is not a trivial one. You have to consider and balance a number of parameters. For example, efficiency vs. speed, less complex or more complex trajectories, cost vs. practicality.

INTERPLANETARY TOURISTS

So, we don't aim straight for Saturn. We don't just curve towards Saturn. {For Cassini, the road to Saturn is both long and winding…a complex but clever routing carefully designed to not exceed the limited fuel available and, at the same time, take advantage of some extra sightseeing and science along the way.}

VIDEO: 1st-2nd Gravity Assist

We will visit a few other planets first – sort of like stepping on stones to get across a river. But instead of hopping from Earth to Mars to Jupiter to Saturn, we will first go from Earth to Venus!

TOP: Flyby of Venus

{More than 5 months after launch Cassini swings by its first port of call – Venus. The planet's gravitational pull tugs on the spacecraft providing a "gravity assist".}

{In so doing, Venus gives Cassini a "kick" speeding it up and redirecting its path. A firing of Cassini's main engine in what is called the Deep Space Maneuver makes an additional adjustment.}

VIDEO: 2nd-4th Gravity Assist

{423 days later, when Cassini crosses the orbit of Venus again, the timing is perfect, for Venus, once again is there to meet it. This second gravity assist sends the spacecraft onward on what will now be a long journey away from the Sun.}

TOP: Crescent Earth

{55 days later, Cassini pays a brief return visit to the home of its creators – our fragile planet spinning in space. Again, a gravity assist is provided and Cassini accelerates still faster. In all, the two Venus encounters and the additional boost from Earth's gravity have saved 75 tons of fuel and kept Cassini on target for its "RingWorld" destination.}

{The encounter with Earth now propels the spacecraft farther and farther from the Sun – across the orbit of Mars, through the asteroid belt, and on to the first of the giant planets, mighty Jupiter.}

TOP: Jupiter

{During the late 1990s, a spacecraft named Galileo arrived here, went into orbit around Jupiter, and provided unprecedented reconnaissance of the planet and many of its satellites.}

VIDEO: Galileo at Jupiter

{Now, in what becomes known as the "Millennium Fly-by", Cassini adds its cameras and scientific instruments to the effort.}

VIDEO continues…

{Working in tandem, Cassini and Galileo map Jupiter's immense magnetic field in three dimensions as high energy particles, streaming from the distant Sun, buffet the field and continually reshape its outer boundaries.}

{As revelers welcome the arrival of 2001 back on Earth, Cassini wraps up its brief sojourn at Jupiter. A final gravity assist from the giant planet is all that is needed to set the stage for the main event – Cassini's encounter with Saturn and its entourage of fascinating satellites.}

ARRIVAL AT SATURN…

{It is mid-June 2004.} ***Do you remember when it launched? [October 1997.]*** {For nearly 7 years, Cassini has cruised the solar system on its way to its target worlds. Now the main work begins.}

TOP: Saturn

To communicate with Saturn, scientists and engineers will be sending signals and receiving data from Cassini. To see what this is like, ***I would like to invite everyone to stand up.***

Have you ever done The Wave at a baseball stadium or other sporting event? [Take any answers.] One person raises their hands, then their neighbor does, then their neighbor and so forth so you see a "wave" of hands go around and around. That can be very similar to what happens with Cassini. If I send a signal starting with you ***[indicate first person]*** that signal can travel along our "wave" until it gets to "Cassini" ***[indicate last person]***. When my Cassini here gets the signal, ***can you say "Received!"?*** While this is happening, I will be counting to see how long this takes.

Send the "signal" and count every second it takes to get to "Cassini".

Now, that took about ___ seconds. However, we don't know Cassini has actually received the signal unless s/he sends a signal back to me. So, when you are ready, ***can you [indicating Cassini] send a signal back to me?*** When I get it, I will say "Acknowledged!" ***How long do you think that will take? [About the same time it took to send the first signal.]***

Allow "Cassini" to send a wave back.

Now, all these signals take time to travel. It takes about ___ seconds to travel through ___ people. For the real Cassini, {even traveling at the speed of light – 186,000 miles per *second* – radio signals will take nearly three hours to make a round trip journey from Earth to Saturn and back.} ***Please have a seat again.***

With such a long lag time, what can we do if Cassini runs into something? [Nothing!] {So engineers have "built the spacecraft smart" to largely think for itself using carefully pre-planned instructions and contingencies in case of emergencies. Things are about to start happening so fast, Cassini will largely be on its own.}

VIDEO: Phoebe flyby

{19 days before Cassini officially arrives at Saturn, it encounters the largest of the planet's outer satellites, Phoebe, which orbits in the opposite direction to most of the other moons.} ***Can you think of why this might be? [Phoebe may be a captured asteroid or the nucleus of an old comet.]*** {Scientists eagerly await their first close-up look.} This will also be the only opportunity to study Phoebe up close, as Cassini will never make it back out this far from Saturn.

TOP: SOI Geometry, top view
SIDE: SOI Geometry, side view

{Cassini races toward its rendezvous with Saturn drawn by the ringed giant's strong gravitational field.}

VIDEO: SOI Burn

{As Cassini plunges onward, its speed approaches 50,000 miles per hour – fast enough to fly coast to coast across the United States in 3 minutes!}

{A moment of truth has arrived – a "hold your breath moment" upon which the entire rest of the mission hangs for, at this speed, Cassini is moving too fast and would simply fly past Saturn.}

{The spacecraft streaks inward skirting just above the rings and then, for nearly 100 minutes, Cassini's main engine fires in just the right way to change the spacecraft's speed by 1300 miles per hour and allow it to drop into orbit around Saturn.}

{Cassini's instruments take advantage of this closest approach to scrutinize the rings and monitor the innermost regions of the planet's magnetic field.}

VIDEO: 3 Saturn Orbits

{For the next 6 months, Cassini completes three carefully executed orbits of Saturn, as images and other data stream toward Earth.}

THE HUYGENS PROBE….

{During these three orbits, engineers also painstakingly adjust Cassini's speed and prepare the spacecraft for the next critical part of the mission.}

{Now, it is time for Cassini's piggybacking Huygens probe to take center stage. The product of the European Space Agency, Huygens' mission is to detach from Cassini, descend into the atmosphere of Saturn's largest satellite, Titan, and actually land on its surface.}

{Many scientists believe the chemistry of Titan's atmosphere mimics that of Earth long ago. If so, Titan may well provide scientists with the equivalent of a "time machine" to travel back to an era before life first developed on our world.}

{A final system's check and then…}

VIDEO continues: Huygens jettison & approach

{15 minutes before Huygens encounters Titan's upper atmosphere, a wake up call sounds and Huygens' array of instruments come alive.}

{Larger than the planets Mercury and Pluto, Titan is one of the most intriguing satellites in the solar system. It has a substantial atmosphere – a thick, smoggy shroud of an atmosphere rich in organic compounds that may hold secrets to the evolution of life on our planet.}

{Batteries on board Huygens will power it for three hours – long enough to keep the probe sending back data throughout its descent and as much as a half hour after it reaches Titan's mysterious surface.}

{The descent phase has begun as Huygens slams into Titan's upper atmosphere at nearly 14,000 miles per hour!}

{Over the next three minutes, temperatures immediately in front of Huygens' heat shield will soar from 300 degrees below zero to over 21,000 degrees Fahrenheit – twice the surface temperature of the Sun!}

{In the same three minutes, atmospheric drag also brakes the probe's speed from nearly 14,000 miles per hour to less than 900!}

VIDEO continues: Titan descent

{At one and a half times the speed of sound, a pilot chute is released, pulling off Huygens' aft cover.}

Main chute follows almost immediately.

{Almost immediately, the probe's main parachute unfurls. We are 110 miles from the surface.}

Huygens continues its descent under the main chute.

{Within 30 seconds, Huygens has slowed to little over half the speed of sound. The heat shield has done its work and is jettisoned.}

Heat shield is jettisoned.

{For the next 15 minutes, the probe descends under its main chute as initial scientific measurements begin.}

Signals are broadcast from Huygens up through the atmosphere.

{High above, Cassini collects the data transmitted by Huygens and stands ready to relay it to Earth.}

Main chute separates from Huygens as a smaller drogue chute is released and the probe continues its descent.

{Finally, a smaller drogue chute takes over. Altitude: 85 miles.}

VIDEO continues: Parachuting through the atmosphere.

{For the next two and a quarter hours, as it continues its descent toward the surface, Huygens' instruments will be busy.}

{They will "sniff" Titan's atmosphere recording its chemical composition as well as make detailed measurements of temperature, pressure, and density. And on-board cameras will stand ready to capture up to 1100 pictures.}

{Finally…the surface. Will Huygens discover multi-colored dunes of hydrocarbon "snows"? Lakes or seas of liquid ethane and methane? Or an even more exotic world? Soon, we will know as Titan gives up its secrets.}

MISSION TOUR

{As Huygens' mission draws to a close, that of Cassini has barely begun. For at least the next three and a half years, Cassini will tour the Saturnian system.}

VIDEO: Tour overview

{Many orbits will bring it back for a pass by Titan for now it is Titan's turn to provide gravity assists – carefully directing Cassini past many of Saturn's other satellites while also providing for detailed reconnaissance of Titan itself. Repeated passes by Titan will also be used to direct the spacecraft on exotic trips well above Saturn's rings. In each case, dramatic new vistas and discoveries await us.}

{Images of Titan taken on successive passages may be used to make dramatic time-lapse movies to better understand weather

systems on this alien world and, perhaps, better understand weather patterns on our own world as well.}

{As Cassini passes behind Titan, scientists will study how radio signals transmitted by the spacecraft are affected by their passage through the satellite's atmosphere. Such studies will help us better understand how Titan's atmosphere varies with location while other passes will aid scientists in figuring out how matter is distributed within this large moon itself.}

{Cassini also carries a sophisticated radar that will pierce the clouds and accurately map portions of Titan's surface. Other satellites will come under close study as well.}

{Cassini will sail past Enceladus where giant ice volcanoes or geysers may resurface the landscape and even blast particles far into space to be captured by and replenish Saturn's outer ring. Past Rhea, a cratered world with mysterious wispy, white streaks – perhaps snow exuded from fractures in its frozen crust. And Dione, another heavily cratered ice moon also showing curious wisp-like features. To Tethys where Ithaca Chasma, an ice canyon 60 miles wide and up to 3 miles deep, cracks this moon nearly pole to pole.}

VIDEO: Rotating Mimas

{Past Mimas with a crater so large – its birth almost shattered this moon to bits.}

SIDE: Hyperion

{Over potato-shaped Hyperion home to amazing ice cliffs over 6 miles high.}

VIDEO: Iapetus

{And Iapetus, a satellite with one face as black as asphalt…and the other as white as newly fallen snow.}

{Cassini will also study Saturn's magnificent rings – nearly 200,000 miles from edge to edge yet no more than a hundred feet thick!}
Does anyone know what the rings are made of? [Take any answers.]

VIDEO: Saturn & Rings & Ring particles

{From a distance, the rings look solid. But in reality, they are an enormous blizzard of millions upon millions of pieces of ice that range in size from grains of sand to boulders larger than a house. Each races around Saturn in a separate orbit at speeds up to 50,000 miles per hour.}

VIDEO: Braids, shepherd moons, spokes

{Cassini will focus in on the mysterious F-ring that appears to periodically braid and unbraid like a girl's hair as well as the F ring's so-called "Shepherding Satellites – Pandora and Prometheus – tiny moons that orbit along its edge, periodically swap places, and, through their gravity, herd would be stray particles back into place.}

{Other orbits will take Cassini on rare excursions high above the rings. From such a vantage point, Cassini will be able to study curious, dark spoke-like features in Saturn's broad B ring that were first discovered by Voyager. Could these "spokes" be dust particles suspended above the ring and swept along by Saturn's magnetic field? Cassini may provide the answer.}

VIDEO continues: Ring density

{In addition, light from selected stars will be scanned as they blink on and off through the intervening rings. From such periodic tracings, scientists will gather valuable information on the size distribution of icy chunks and particles within the rings and how the rings change over time.}

EXTENDED MISSION….

{While this "Tour Phase" of Cassini's mission is scheduled to last 4 years, the spacecraft may well remain in good health long thereafter. If so, the mission may be extended to have a closer look at new discoveries encountered along the way or take on a "higher risk assignment beyond the scope of the regular mission.}

{One possibility would be additional close fly-bys of Titan to improve radar mapping of the surface and perhaps ultimately send the spacecraft on deeper and deeper sojourns through the satellite's atmosphere.}

{Another plan would have the spacecraft make a higher risk passage just outside the rings or even through Cassini's Division to obtain even closer scrutiny of these incredible features.}

{In the future, other missions will follow. One currently on the drawing boards would see an orbiting spacecraft fire one or more special advanced probes into Titan's atmosphere.}

SIDE: Aerobot descending

{Known as aerial mobile technology, or aerobot for short, such balloon carrying laboratories could fly below Titan's clouds for extreme close-up imaging of the exotic features that may be found there. Unlike Huygens, the aerobots could carry instruments on extended flights over this most alien world – flights that may last for weeks or even months (and cover thousands of miles).}

CONCLUSION

{Exotic worlds lie at our doorstep. Soon, they will be opened to us like never before and we can only wonder what new wonders we shall soon behold.}

TOP: Saturn

{And, in the center of it all – Saturn! Ancient god, magnificent celestial jewel, object of intense fascination – to artists, poets, and scientists alike. Soon, we will return – this time to stay.}

VIDEO: Cassini '97-'08