Part 6

No. 1

S·P·A·C·E TOURISM™

Lecture Series given by Dr.-Ing. Robert Alexander Goehlich

Part 6

No. 2

S·P·A·C·E TOURISM™

Lecture Series given by Dr.-Ing. Robert Alexander Goehlich

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- **Rocket Science**
  - Ideal Rocket Equation
  - Earth‘s Atmosphere
  - Solar System
  - Newton‘s Laws
  - Kepler‘s Laws
- **Requests from Audience for Future Lectures**
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内容

No. 4

- **はじめに**
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  - ロケット方程式
  - 大気
  - 太陽系
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General

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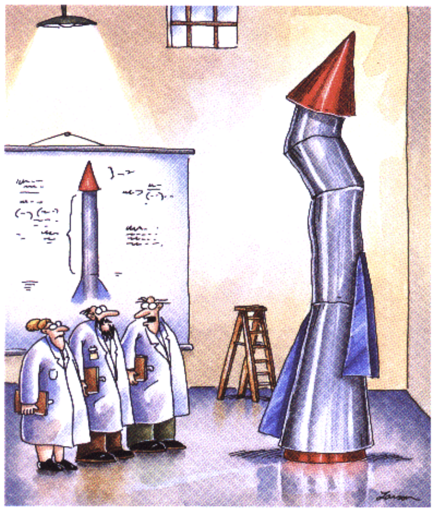
General

Goal of Today‘s Lecture

No. 7

„You will learn about basics of rocket science and do some exercises with selected examples.“



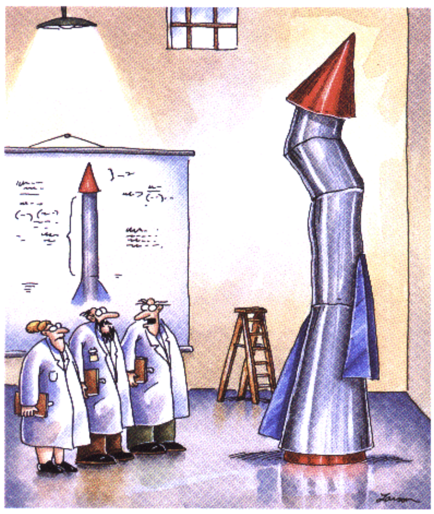
"It's time we face reality, my friends. … We're not exactly rocket scientists."

はじめに

本日の講義目的

No. 8

„ロケット理論の基礎を学習するとともに, いくつかの例題を解いて理解を深めていただきます “



"It's time we face reality, my friends. … We're not exactly rocket scientists."

Rocket Equation

No. 9

$$\Delta p_{\mathrm{exhaust}} = dM(u+v)$$

$$\Delta p_{\mathrm{rocket}} = (M - dM)\, du.$$

$$dM\,(u+v) = (M - dM)\, du \approx M\, du.$$

$$M\, du + dM = 0 \quad \text{if} \quad u \ll v$$

$$du = -v \frac{dM}{M}$$

$$\int_{u_0}^{u} du = -v \int_{M_0}^{M} \frac{dM'}{M'},$$

$$u = v \ln\left(\frac{M_0}{M}\right) + u_0.$$

where *u* is the final rocket velocity, *v* is the velocity of the exhaust gases, *M_0 is the starting mass, M* is the ending mass of the rocket and u_0 is the initial rocket velocity prior to the fuel burn. This equation was published by Tsiolkovsky in 1903.

ロケット方程式

No. 10

$$\Delta p_{\mathrm{exhaust}} = dM(u+v)$$

$$\Delta p_{\mathrm{rocket}} = (M - dM)\, du.$$

$$dM\,(u+v) = (M - dM)\, du \approx M\, du.$$

$$M\, du + dM = 0 \quad \text{if} \quad u \ll v$$

$$du = -v \frac{dM}{M}$$

$$\int_{u_0}^{u} du = -v \int_{M_0}^{M} \frac{dM'}{M'},$$

$$u = v \ln\left(\frac{M_0}{M}\right) + u_0.$$

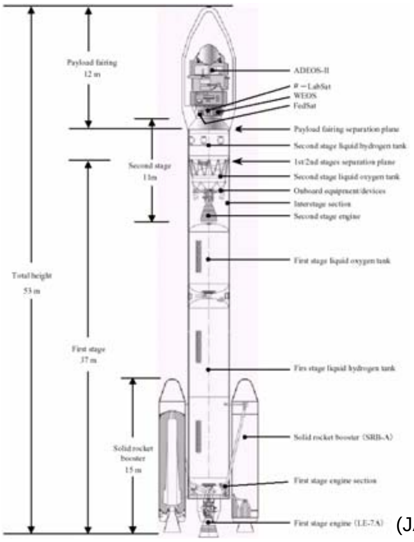
U: 最終速度, v: 有効排気速度, M_0: 離陸時の質量, M: 最終質量, u_0: 初期速度

この方程式は1903年にツィオルコフスキーによって発表されました。

Rocket Equation

Launch Vehicle Configuration (HII-A F4)

No. 11

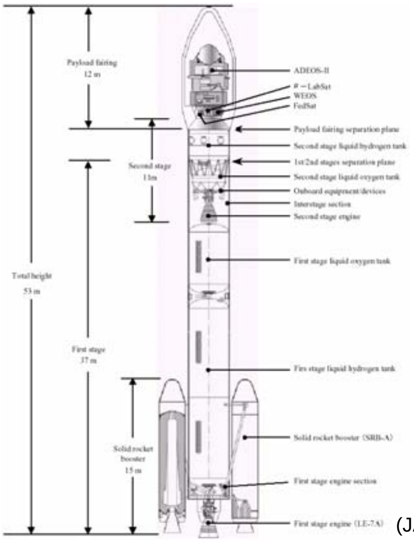


(JAXA)

ロケット方程式

打ち上げロケットの構成（HII-A F4）

No. 12



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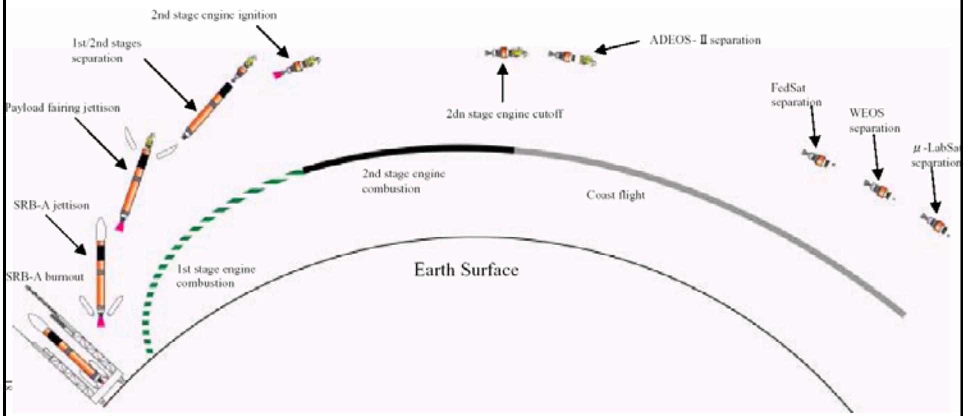
Rocket Equation

Launch Vehicle Flight Sequence (HII-A F4) No. 13



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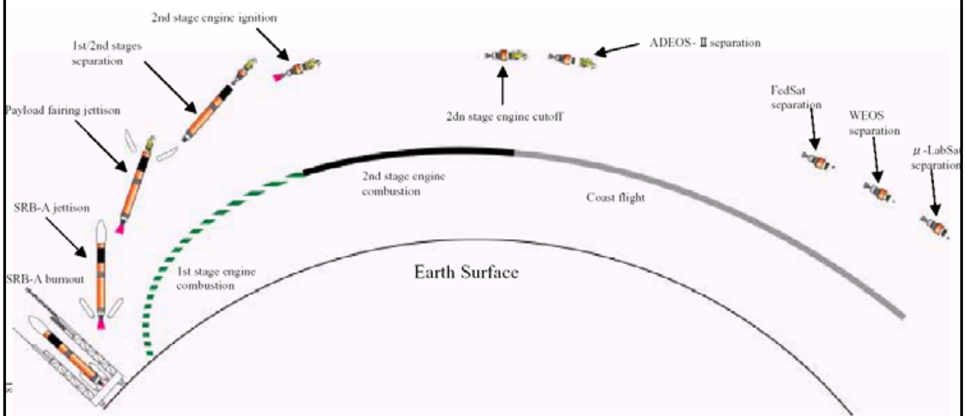
ロケット方程式

打ち上げロケットの飛行プロファイル（HII-A F4）No. 14



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Rocket Equation

Launch Vehicle Flight Plan (HII-A F4)

No. 15

Event	Time passed after liftoff		Distance on earth	Altitude	Inertial velocity
	hour min.	sec.	km	km	km/s
1 Liftoff	0	0	0	0	0.4
2 Solid Rocket Booster (SRB-A) burnout	1	40	20	50	1.3
3 SRB-A jettison	1	47	23	57	1.3
4 Payload fairing jettison	4	20	153	202	1.8
5 1st stage engine cutoff	6	35	404	390	3.6
6 1st/2nd stages separation	6	43	426	405	3.6
7 2nd stage engine ignition	6	49	443	416	3.5
8 2nd stage engine cutoff	15	38	2662	808	7.4
9 ADEOS-II separation	16	28	2995	808	7.4
10 FedSat separation	30	55	8764	824	7.4
11 WEOS separation	32	40	9462	826	7.4
12 μ−LabSat separation	34	30	10193	828	7.4

(JAXA)

ロケット方程式

打ち上げロケットの飛行計画（HII-A F4）

No. 16

Event	Time passed after liftoff		Distance on earth	Altitude	Inertial velocity
	hour min.	sec.	km	km	km/s
1 Liftoff	0	0	0	0	0.4
2 Solid Rocket Booster (SRB-A) burnout	1	40	20	50	1.3
3 SRB-A jettison	1	47	23	57	1.3
4 Payload fairing jettison	4	20	153	202	1.8
5 1st stage engine cutoff	6	35	404	390	3.6
6 1st/2nd stages separation	6	43	426	405	3.6
7 2nd stage engine ignition	6	49	443	416	3.5
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12 μ−LabSat separation	34	30	10193	828	7.4

(JAXA)

Rocket Equation

HII-A F4 Launch (Part 1)

No. 17

(movie)

ロケット方程式

HII-A F4の打ち上げ（パート 1）

No. 18

(movie)

Rocket Equation

HII-A F4 Launch (Part 2)

No. 19

(movie)

ロケット方程式

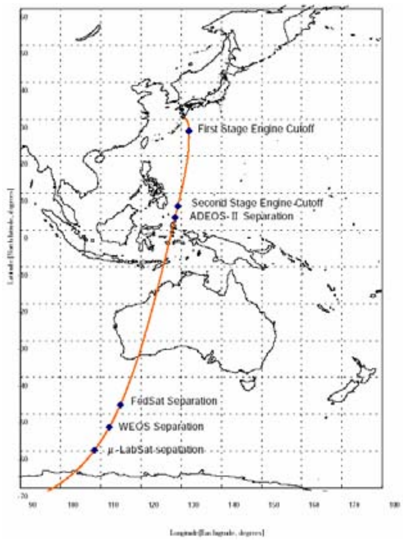
HII-A F4 の打ち上げ(パート 2)

No. 20

(movie)

Rocket Equation
Launch Vehicle Trajectory (HII-A F4)

No. 21



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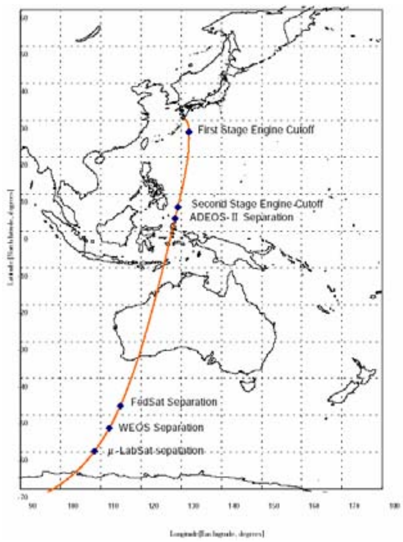
ロケット方程式
打ち上げロケットの軌道 (HII-A F4)

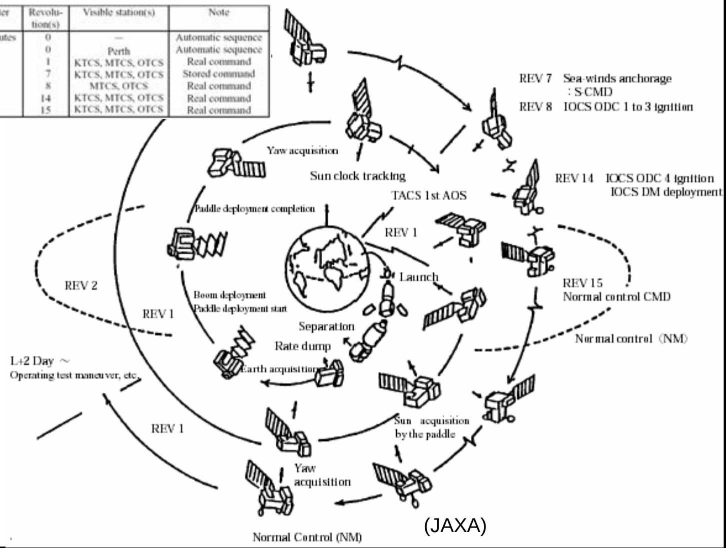
No. 22



(JAXA)

Rocket Equation
Major On-orbit Events (ADEOS-II)

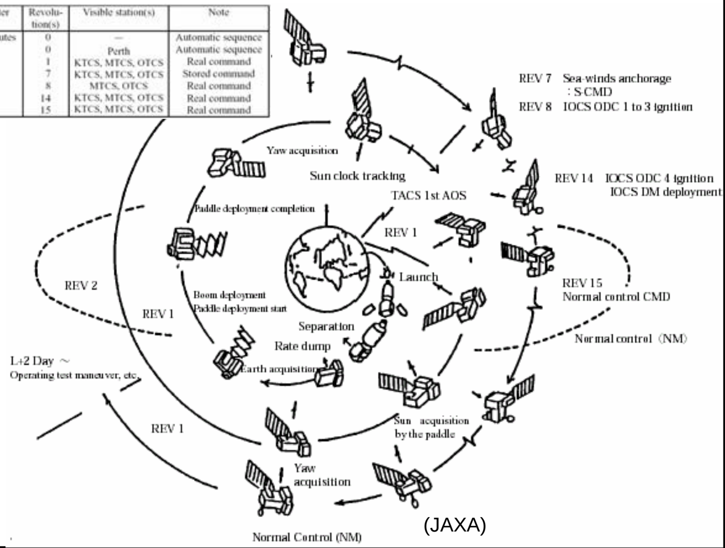
Event	Time passed after liftoff		Revolution(s)	Visible station(s)	Note
1) 2nd stage/ADEOS-II separation	00 hour(s)	15minutes	0	—	Automatic sequence
2) Paddle deployment	00	25	0	Perth	Automatic sequence
3) Paddle sun acquisition start	01	33	1	KTCS, MTCS, OTCS	Real command
4) SeaWinds anchorage	12	15	7	KTCS, MTCS, OTCS	Stored command
5) IOCS deployment 1	13	01	8	MTCS, OTCS	Real command
6) IOCS deployment 2	23	36	14	KTCS, MTCS, OTCS	Real command
7) Move to normal control mode	25	18	15	KTCS, MTCS, OTCS	Real command



(JAXA)

ロケット方程式
軌道上イベント (ADEOS-II)

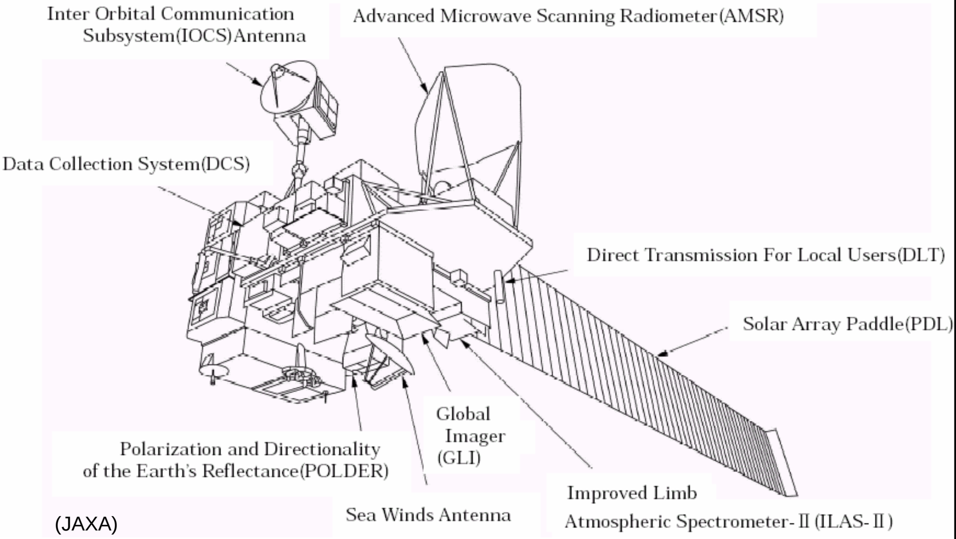
Event	Time passed after liftoff		Revolution(s)	Visible station(s)	Note
1) 2nd stage/ADEOS-II separation	00 hour(s)	15minutes	0	—	Automatic sequence
2) Paddle deployment	00	25	0	Perth	Automatic sequence
3) Paddle sun acquisition start	01	33	1	KTCS, MTCS, OTCS	Real command
4) SeaWinds anchorage	12	15	7	KTCS, MTCS, OTCS	Stored command
5) IOCS deployment 1	13	01	8	MTCS, OTCS	Real command
6) IOCS deployment 2	23	36	14	KTCS, MTCS, OTCS	Real command
7) Move to normal control mode	25	18	15	KTCS, MTCS, OTCS	Real command



(JAXA)

Rocket Equation
On-orbit Configuration (ADEOS-II)

No. 25



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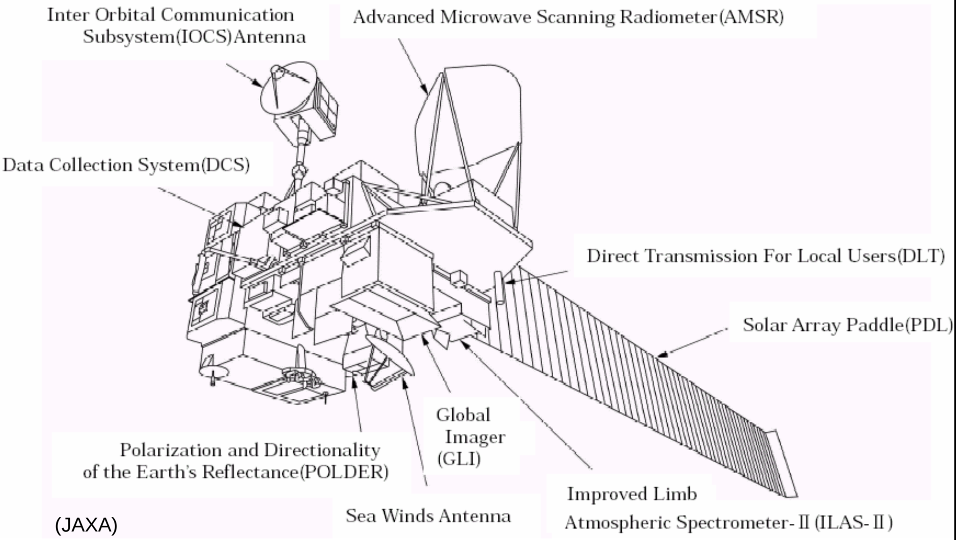
ロケット方程式
構成（ADEOS-II）

No. 26



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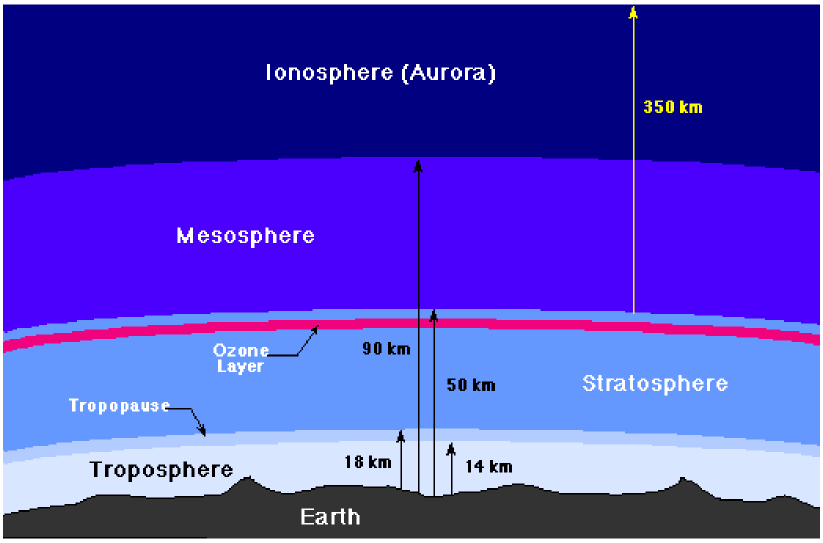
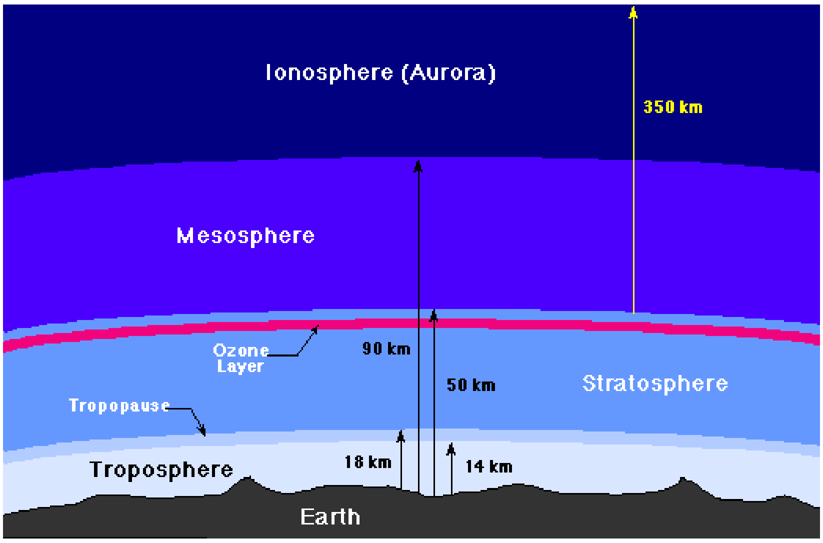
Earth's Atmosphere

No. 27



大気

No. 28

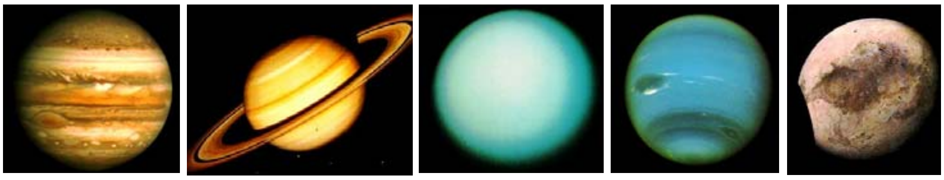


Solar System

No. 29

Sun Mercury Venus Earth Mars

 Asteroids 



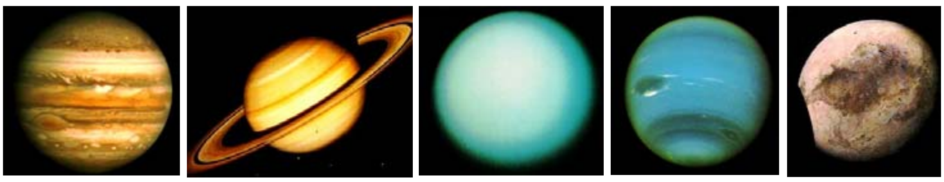
Jupiter Saturn Uranus Neptune Pluto

太陽系

No. 30

太陽 水星 金星 地球 火星

 小惑星 



木星 土星 天王星 海王星 冥王星

Solar System
Realtime Simulation

No. 31

太陽系
シミュレーション

No. 32

Earth Orbits

No. 33

Geostationary Orbits (GEO):

are circular, low inclination orbits around the Earth having a period of 24 hours. A spacecraft in a geosynchronous orbit appears to hang motionless above one position on the Earth's surface.

Polar Orbits (PO):

are orbits with an inclination of 90 degrees. Polar orbits are useful for satellites that carry out mapping operations because as the planet rotates the spacecraft has access to virtually every point on the planet's surface.

Sun Synchronous Orbits (SSO):

are walking orbits whose orbital plane precesses with the same period as the planet's solar orbit period. In such an orbit, a satellite crosses periapsis at about the same local time every orbit.

地球の軌道

No. 34

静止軌道（GEO）:

24時間周期で地球をまわる低軌道傾斜角の円軌道です。静止軌道上の宇宙機は地球表面上の上空で止まって見えます。

極軌道（PO）:

90度の軌道傾斜角を持つ軌道です。この軌道は惑星が自転するにつれて宇宙機が惑星表面に近接することができるため、地図作成のミッションを持つ衛星にとっては非常に便利な軌道です。

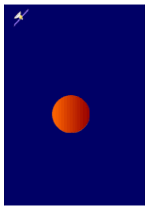
太陽同期軌道（SSO）:

惑星の太陽同期周期と同じ周期の軌道平面を持つ軌道です。衛星はどの軌道でも同じ時間で近点を通過します。

Newton's Laws

No. 35

1. Every body continues in a state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.



2. The change of motion (linear momentum) is proportional to the force impressed and is made in the direction of the straight line in which that force is impressed.

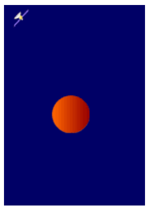
$$F = ma$$

3. To every action there is always an equal and opposite reaction; or, the mutual actions of two bodies upon each other are always equal, and act in opposite directions.

ニュートンの法則

No. 36

1. 静止状態あるいは直線運動を行なっているどのような物体も，力を受けない限りその状態を維持し続ける



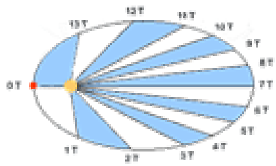
2. 運動量の変化は与えられた力に比例し，力の加わる方向に運動をする

$$F = ma$$

3. 二体間に働くどのような運動にも，同じ大きさで方向の異なる力が発生する

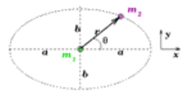
Kepler's Laws

1. If two bodies interact gravitationally, each will describe an orbit that is a conic section about the common mass of the pair. If the bodies are permanently associated, their orbits will be ellipses. If they are not permanently associated with each other, their orbits will be hyperbolas (open curves).
2. If two bodies revolve around each other under the influence of a central force (whether or not in a closed elliptical orbit), a line joining them sweeps out equal areas in the orbital plane in equal intervals of time.
3. Stating that the ratio of the square of the revolutionary period (in years) to the cube of the orbital axis (in astronomical units) is the same for all planets



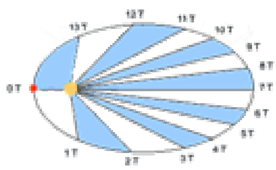
T = any unit of time (hour, day, week, etc.)

$$T_a^2 / T_b^2 = R_a^3 / R_b^3$$



ケプラーの法則

1. 引力によって二体間に力が発生しあっている場合, どちらの物体も二体の質量によって決まる円錐軌道を描く。この物体間の関係が不変ならば, この軌道は楕円形となる。そうでない場合は, 放物線軌道となる。
2. 二つの物体が中心力のみによって互いの周りを回っているのならば, 軌道面内で一定時間内に二体の掃く面積は一定となる。
3. 軌道の回転周期の2乗と軌道軸長さの3乗との比率はどんな惑星でも一定となる。



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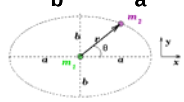
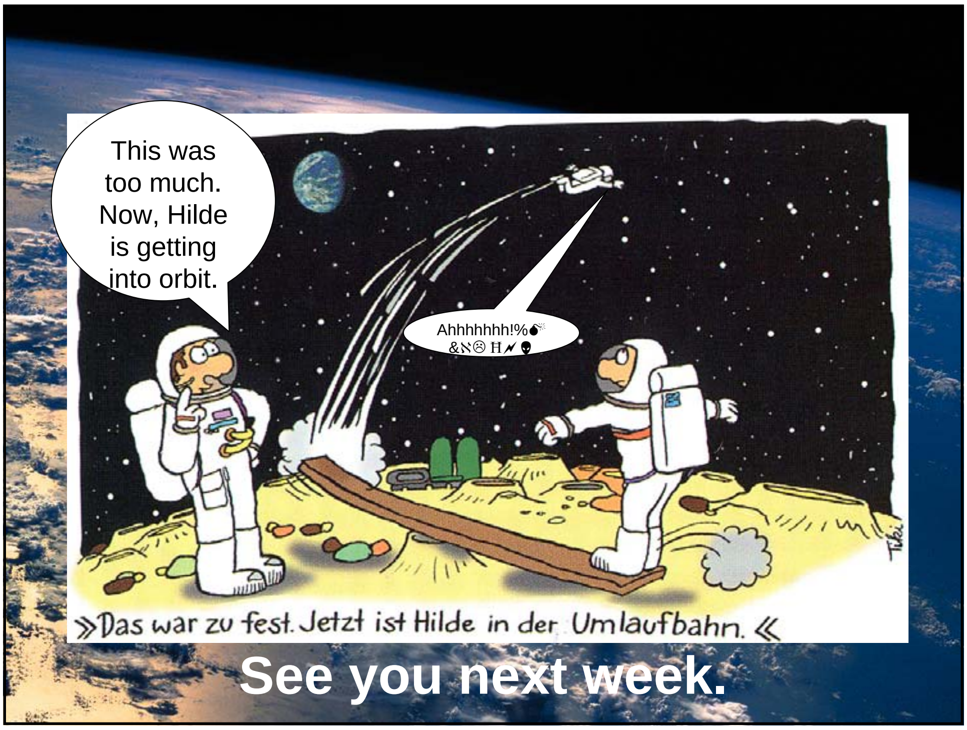
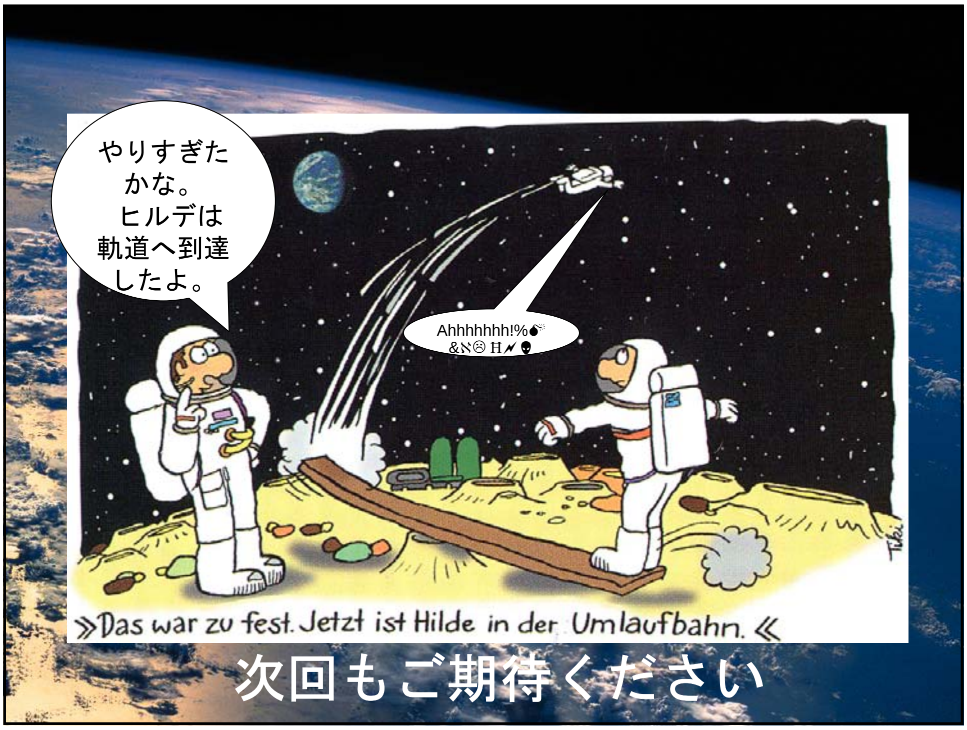



This was too much. Now, Hilde is getting into orbit.
Ahhhhhhh!%
»Das war zu fest. Jetzt ist Hilde in der Umlaufbahn.«
See you next week.


やりすぎたかな。 ヒルデは軌道へ到達したよ。
Ahhhhhhh!%
»Das war zu fest. Jetzt ist Hilde in der Umlaufbahn.«
次回もご期待ください