

Solar System

August 7, 2020

Positions of Solar System bodies and effective distances between them for communication and travel.

1 Inner System

The inner system map shows positions of notable objects inside Jupiter's orbit. Future orbit positions are displayed for some bodies at one month intervals.

Tycho Station The Belt headquarters of Tycho Manufacturing and Engineering Concern is the largest mobile construction platform in the Sol System. Fifteen thousand workers and their families live within Tycho, building megastructures or massive ships far beyond the reach of a planet.

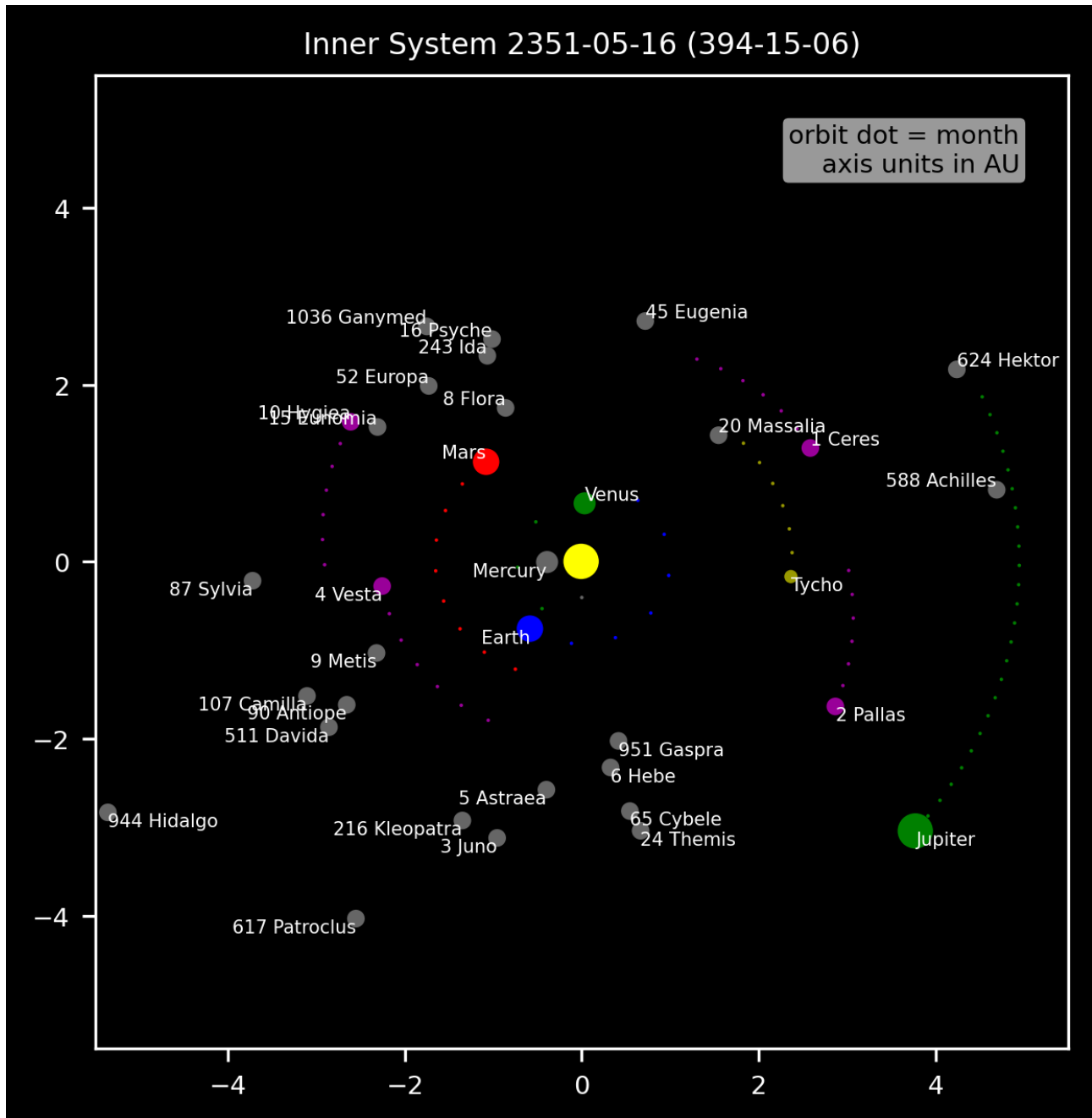
1.1 Colonized Asteroids

- 1 Ceres** The only dwarf planet in the inner solar system, and the first asteroid discovered by humanity. Tycho corporation spun up the asteroid in a dramatic feat of engineering, granting it a gravity of 0.3 g. Now the most important port of call in the Belt with population of approximately six million permanent residents
- 2 Pallas** The third largest asteroid in the Asteroid Belt, and the second asteroid discovered by humanity. It hosts one of the oldest stations, Pallas Station, in the outer planets, but is also known for a revolt at its colony. The station itself has a long history of a refinement station for the mining operations of the Belt. Due to this legacy, it continues to have its infrastructure maintained and upgraded, making use of its older equipment as overflow capacity.
- 4 Vesta** The second-most-massive asteroid in the Asteroid Belt after Ceres. It hosts one of the largest settlements in the outer planets. At some time during the UN-MCR Cold War, Vesta was the site of the Vesta Blockade, a confrontation between the UN and MCR that would delay the Martian terraforming efforts for over a century.
- 10 Hygiea** The fourth largest asteroid in the Asteroid Belt and somewhat oblong. It hosts Hygeia Station. Like many places in the Belt, its population suffered from high UN taxes that made survival expensive and kept the population routinely destitute.

1.2 Other Notable asteroids

- 3 Juno** One of the two largest stony asteroids, along with 15 Eunomia. It is estimated to contain 1% of the total mass of the Asteroid Belt. Its orbit has an extreme eccentricity which brings Juno closer to the Sun at perihelion than Vesta and further out at aphelion than Ceres.
- 5 Astraea** The fifth asteroid discovered. Physically unremarkable but notable because after its discovery, thousands of other asteroids would follow. The discovery of Astraea proved to be the starting point for the eventual demotion of the four original asteroids (which were regarded as planets at the time) to their current status.
- 6 Hebe** Large main-belt asteroid, containing around 0.5% of the mass of the Belt. This high bulk density means an extremely solid body that has not been impacted by collisions, which is not typical of asteroids of its size. In brightness, Hebe is the fifth-brightest object in the Asteroid Belt.
- 8 Flora** Large, bright main-belt asteroid. It is the innermost large asteroid: no asteroid closer to the Sun has a diameter above 25 kilometres or two-elevenths that of Flora itself, and not until the tiny 149 Medusa was discovered was a single asteroid orbiting at a closer mean distance known.
- 9 Metis** One of the larger main-belt asteroids. It is composed of silicates and metallic nickel-iron, and may be the core remnant of a large asteroid that was destroyed by an ancient collision. Metis is estimated to contain just under half a percent of the total mass of the Asteroid Belt.

- 15 Eunomia** The largest of the stony asteroids. Eunomian family is the most prominent family in the intermediate asteroid belt and the 6th-largest family with nearly six thousand known members, or approximately 1.4% of all asteroids in the Asteroid Belt.
- 16 Psyche** One of the most massive asteroids in the asteroid belt. This object is over 200 km in diameter and contains about 1% of the mass of the entire asteroid belt. It is thought to be the exposed iron core of a protoplanet, and is the most massive metallic M-type asteroid.



- 20 Massalia** Stony asteroid and the parent body of the Massalia family located in the inner region of the asteroid belt, approximately 145 kilometers in diameter. The family is fairly young, estimated to have been created by an impact 150 to 200 million years ago.
- 24 Themis** The largest member of the Themistian family with surface completely covered in ice. There is also organic compounds in the form of tholins, high-molecular weight organics found in the outer solar system, distinguished by a brown or reddish color in optical spectra.
- 45 Eugenia** Famed as one of the first asteroids to be found to have a moon orbiting it, and the first one to been discovered by an Earth-based telescope. Eugenia I Petit-Prince is the larger (diameter of 13 km), outer moon. A second, smaller (diameter of 6 km) satellite orbits closer to Eugenia.

- 52 Europa** The 6th-largest asteroid in the asteroid belt, having an average diameter of around 315 km. It is not round but is shaped like an ellipsoid of approximately $380 \times 330 \times 250$ km. Europa is a very dark carbonaceous C-type, and is the second largest of this group.
- 65 Cybele** One of the largest asteroids in the Solar System and is located in the outer asteroid belt. It gives its name to the Cybele group of asteroids that orbit outward from the Sun from the 2:1 orbital resonance with Jupiter. The last outpost of an extended asteroid belt.
- 87 Sylvia** The 8th-largest asteroid in the asteroid belt. It is the parent body of the Sylvia family and member of Cybele group located beyond the core of the belt. Sylvia was the first asteroid known to possess more than one moon. They have been named (87) Sylvia I Romulus and (87) Sylvia II Remus.
- 90 Antiope** A double asteroid in the outer asteroid belt. It was found to consist of two almost-equally-sized bodies orbiting each other. At average diameters of about 88 km and 84 km, both components are among the 500 largest asteroids.
- 107 Camilla** One of the largest asteroids from the outermost edge of the asteroid belt, approximately 220 kilometers. It is a member of the Sylvia family and located within the Cybele group. The X-type asteroid is a rare trinary asteroid with two minor-planet moons.
- 216 Kleopatra** A metallic, ham-bone-shaped asteroid and trinary system orbiting in the central region of the asteroid belt, approximately 138 kilometers in diameter. It is believed that Kleopatra's shape, rotation, and moons are due to an oblique impact perhaps 100 million years ago.

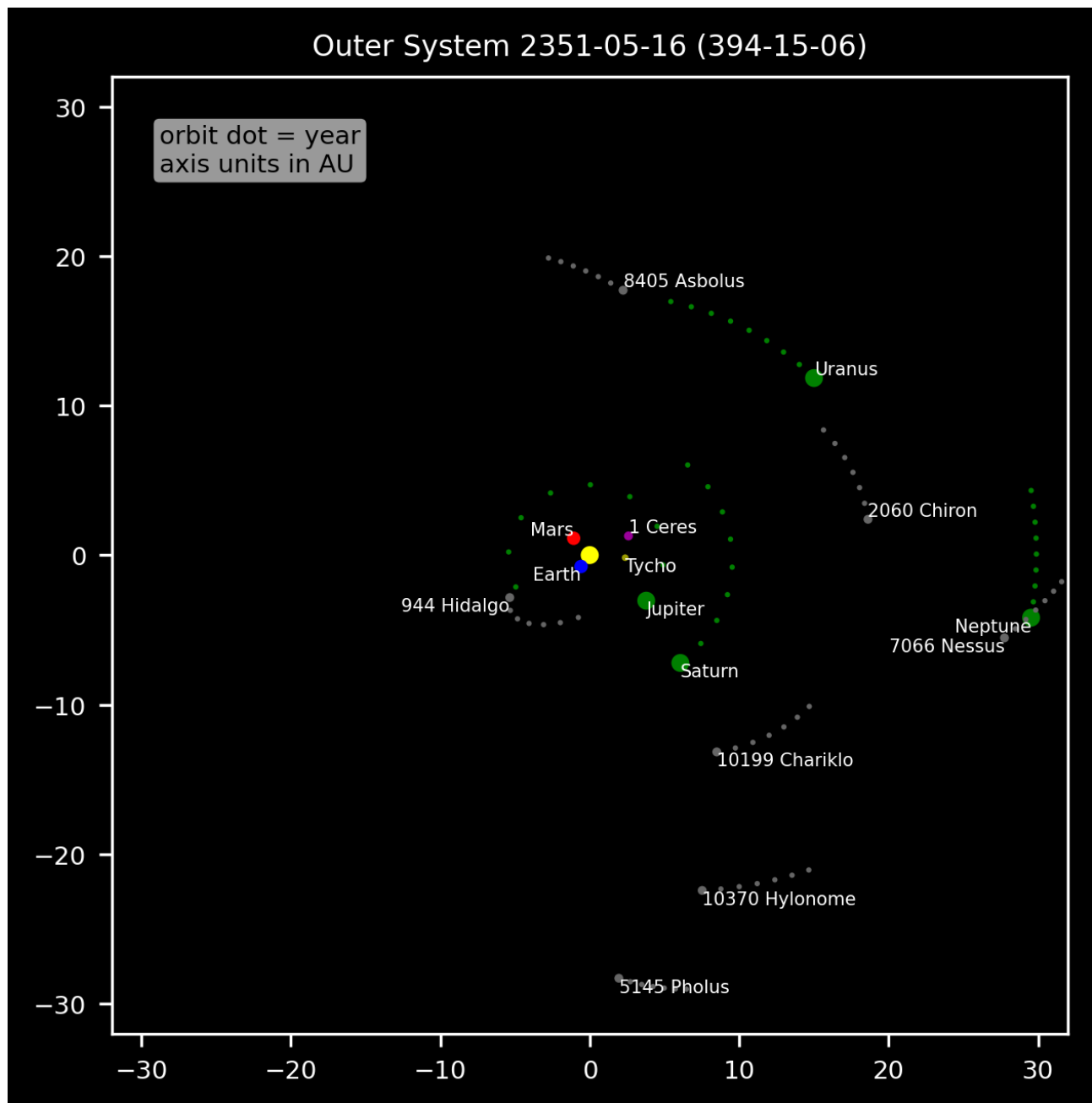


- 243 Ida** An asteroid in the Koronis family of the asteroid belt. It was the second asteroid visited by a spacecraft and the first found to have a natural satellite. Ida's moon Dactyl is only 1.4 kilometres in diameter, about 1/20 the size of Ida.
- 511 Davida** One of the ten most-massive asteroids, and the 7th-largest asteroid. It is approximately 270–310 km in diameter and comprises an estimated 1.5% of the total mass of the Asteroid Belt. It is a C-type asteroid, which means that it is dark in colouring with a carbonaceous chondrite composition.
- 588 Achilles** Large Jupiter trojan from the Greek camp. Archillies was the first Jupiter trojan to be discovered. The dark D-type asteroid measures approximately 133 kilometers in diameter which makes it one of the 10 largest Jupiter trojans.
- 617 Patroclus** A binary Jupiter trojan approximately 140 kilometers in diameter. It was the second trojan to be discovered and the only member of the Trojan camp named after a Greek character. The dark D-type asteroid is also slow rotator and one of the largest Jupiter trojans.
- 624 Hektor** The largest Jupiter trojan and the namesake of the Hektor family, with a highly elongated shape equivalent in volume to a sphere of approximately 225 to 250 kilometers diameter. It has one small 12-kilometer sized satellite, Skamandrios.

- 944 Hidalgo** A centaur and unusual object on an eccentric, cometary-like orbit between the asteroid belt and the outer Solar System, approximately 52 kilometers in diameter. It is the first member of the dynamical class of centaurs ever to be discovered.
- 951 Gaspra** An S-type asteroid that orbits very close to the inner edge of the asteroid belt. Gaspra was the first asteroid ever to be closely approached when it was visited by the Galileo spacecraft, which flew by on its way to Jupiter on 29 October 1990.
- 1036 Ganymed** A stony asteroid on a highly eccentric orbit, classified as a near-Earth object of the Amor group. With a diameter of 35 kilometers, Ganymed is the largest of all near-Earth objects. Amor asteroids is a subgroup of the near-Earth asteroids that approach the orbit of Earth from beyond, but do not cross.

2 Outer System

The outer system map shows positions of giant planets within orbit of Neptune. Earth, Mars and some asteroid colonies are included for reference. Future orbit positions are displayed for some objects at one year intervals.



2.1 Centaurs

Centaurs are small Solar System bodies with either a perihelion or a semi-major axis between those of the outer planets. They generally have unstable orbits because they cross or have crossed the orbits of one or more of the giant planets; almost all their orbits have dynamic lifetimes of only a few million years. Centaurs typically behave with characteristics of both asteroids and comets.

944 Hidalgo The first member of the dynamical class of centaurs ever to be discovered. The dark D-type object has a rotation period of 10.1 hours and an elongated shape. Its orbit takes it to the inner edge of the Asteroid Belt and as far out as to the orbit of Saturn.

2060 Chiron Although Chiron was initially called an asteroid and classified only as a minor planet with the designation "2060 Chiron", it was later found to exhibit behavior typical of a comet. Today it is classified as both a minor planet and a comet.

5145 Pholus An eccentric centaur in the outer Solar System, approximately 180 kilometers in diameter, that crosses the orbit of both Saturn and Neptune. The very reddish object has an elongated shape and a rotation period of 9.98 hours. It was the second centaur to be discovered.

7066 Nessus A centaur on an eccentric orbit, located beyond Saturn in the outer Solar System. The dark and reddish minor planet is elongated and measures approximately 60 kilometers in diameter. It has a relatively long orbital half-life of about 4.9 million years.

8405 Asbolus A centaur orbiting in the outer Solar System between the orbits of Jupiter and Neptune. It measures approximately 80 kilometers in diameter and has a fresh impact crater on its surface, less than 10 million years old.

10199 Chariklo The largest centaur with a diameter of 232 km. It orbits the Sun between Saturn and Uranus, grazing the orbit of Uranus. Chariklo has two ice rings (named Oiapoque and Chui) with radii 396 and 405 km and widths of about 7 km and 3.5 km respectively.

10370 Hylonome A minor planet orbiting in the outer Solar System. The dark and icy body belongs to the class of centaurs and measures approximately 75 kilometers in diameter. It is a Neptune-crosser, and an outer-grazer of the orbit of Uranus, which it hence does not cross.

3 Communication Delay

One of the few true constants in the universe remains the speed of light. Whether communications are sent as radio waves or on the laser of a tightbeam, they travel 300,000 kilometers per second. Often a message can be slowed while the receiver waits for redundant copies of lost packets of data to arrive, or for a message to work its way to the top of the queue at a tightbeam relay station and get passed along on the next stage of its journey. Worse, a distance of 15 light minutes between Earth and Ceres doesn't mean it takes 15 minutes to establish a connection: it means it takes 15 minutes for the first part of the message to travel the distance ("How are you?"), then another 15 minutes for the reply to return ("I'm fine, thanks."). Conversations of alternating messages can take hours or days to complete. Because of this, most transmitted conversations are sent as recorded messages rather than attempting a live conversation, unless the light-speed delay is only a few seconds.

Communication Delay in Minutes 2351-05-16 (394-15-06)

	Mercury	Venus	Earth	Mars	Tycho	Ceres	Pallas	Vesta	Hygiea	Jupiter	Saturn
Mercury	0	6.9	7.1	12	23	27	30	16	23	45	85
Venus	6.9	0	14	10	21	22	30	21	23	46	88
Earth	7.1	14	0	18	25	32	30	15	27	42	81
Mars	12	10	18	0	31	31	40	16	13	56	97
Tycho	23	21	25	31	0	12	13	38	44	30	72
Ceres	27	22	32	31	12	0	24	42	43	39	81
Pallas	30	30	30	40	13	24	0	44	53	19	60
Vesta	16	21	15	16	38	42	44	0	16	57	94
Hygiea	23	23	27	13	44	43	53	16	0	67	107
Jupiter	45	46	42	56	30	39	19	57	67	0	42
Saturn	85	88	81	97	72	81	60	94	107	42	0

Communication delay between planet's moons is usually less than 10 seconds. Delay between Earth and Moon is about 1.3 seconds.

4 Travel Times

Because the Epstein Drive removed Δv limitations to space travel, ships no longer needed to execute Hohmann transfers to maneuver between bodies. To transfer, ships can simply burn prograde at a constant rate, then flip around and decelerate by burning retrograde. This maneuver is called a Brachistochrone trajectory, from the Greek meaning “shortest time.” A course using this maneuver tends to be curved as it uses the sun’s gravity to increase the ship’s acceleration.

The time it takes to execute a flight path along a Brachistochrone trajectory depends on two factors: the distance between the two points, and the acceleration of the ship. The greater the acceleration, the less time it takes to travel, but the multiple g-forces created by these “hard burns” are extremely stressful on the human body. Crash couches and pharmaceutical cocktails like “the juice” alleviate some, but not all, of the damage inflicted by the hardest burns.

The following tables show the time to travel the average distance between the two locations at an average acceleration of 0.5g and 1.0g, presented as total required travel time under acceleration without any of the necessary breaks taken into consideration. The first one is tolerable for belters and the second one suitable for earthers.

Travel Time in Hours (0.5g) 2351-05-16 (394-15-06)

	Mercury	Venus	Earth	Mars	Tycho	Ceres	Pallas	Vesta	Hygiea	Jupiter	Saturn
Mercury	0	88.3	90	116	161	175	185	133	162	224	310
Venus	88.3	0	125	108	153	158	185	153	163	228	315
Earth	90	125	0	142	169	189	184	131	174	218	302
Mars	116	108	142	0	187	187	214	133	123	251	331
Tycho	161	153	169	187	0	118	121	209	223	183	285
Ceres	175	158	189	187	118	0	166	219	222	211	303
Pallas	185	185	184	214	121	166	0	223	245	146	261
Vesta	133	153	131	133	209	219	223	0	135	253	327
Hygiea	162	163	174	123	223	222	245	135	0	276	349
Jupiter	224	228	218	251	183	211	146	253	276	0	219
Saturn	310	315	302	331	285	303	261	327	349	219	0

Travel Time in Hours (1.0g) 2351-05-16 (394-15-06)

	Mercury	Venus	Earth	Mars	Tycho	Ceres	Pallas	Vesta	Hygiea	Jupiter	Saturn
Mercury	0	62.5	63.6	81.8	114	124	131	94.4	114	159	219
Venus	62.5	0	88.6	76.3	108	111	131	108	115	161	223
Earth	63.6	88.6	0	100	120	134	130	92.4	123	154	214
Mars	81.8	76.3	100	0	132	132	151	93.8	86.7	177	234
Tycho	114	108	120	132	0	83.3	85.5	148	158	129	202
Ceres	124	111	134	132	83.3	0	118	155	157	149	214
Pallas	131	131	130	151	85.5	118	0	158	173	103	185
Vesta	94.4	108	92.4	93.8	148	155	158	0	95.1	179	231
Hygiea	114	115	123	86.7	158	157	173	95.1	0	195	247
Jupiter	159	161	154	177	129	149	103	179	195	0	155
Saturn	219	223	214	234	202	214	185	231	247	155	0

The last table starts and ends journey with acceleration boost. The central part of the journey uses normal 0.5g acceleration and flip at the middle.

Travel Time in Hours (0.5g + 6.0g x 4.0h) 2351-05-16 (394-15-06)

	Mercury	Venus	Earth	Mars	Tycho	Ceres	Pallas	Vesta	Hygiea	Jupiter	Saturn
Mercury	0	39.5	40.6	59.8	97.7	109	119	74	97.9	155	235
Venus	39.5	0	67.4	53.7	90.3	94.4	119	90.2	98.9	158	240
Earth	40.6	67.4	0	81.1	105	122	118	71.8	109	148	228
Mars	59.8	53.7	81.1	0	120	120	144	73.3	65.2	179	255
Tycho	97.7	90.3	105	120	0	61.4	63.9	140	153	117	212
Ceres	109	94.4	122	120	61.4	0	102	149	152	142	229
Pallas	119	119	118	144	63.9	102	0	154	174	84.4	189
Vesta	74	90.2	71.8	73.3	140	149	154	0	74.9	182	252
Hygiea	97.9	98.9	109	65.2	153	152	174	74.9	0	203	273
Jupiter	155	158	148	179	117	142	84.4	182	203	0	150
Saturn	235	240	228	255	212	229	189	252	273	150	0