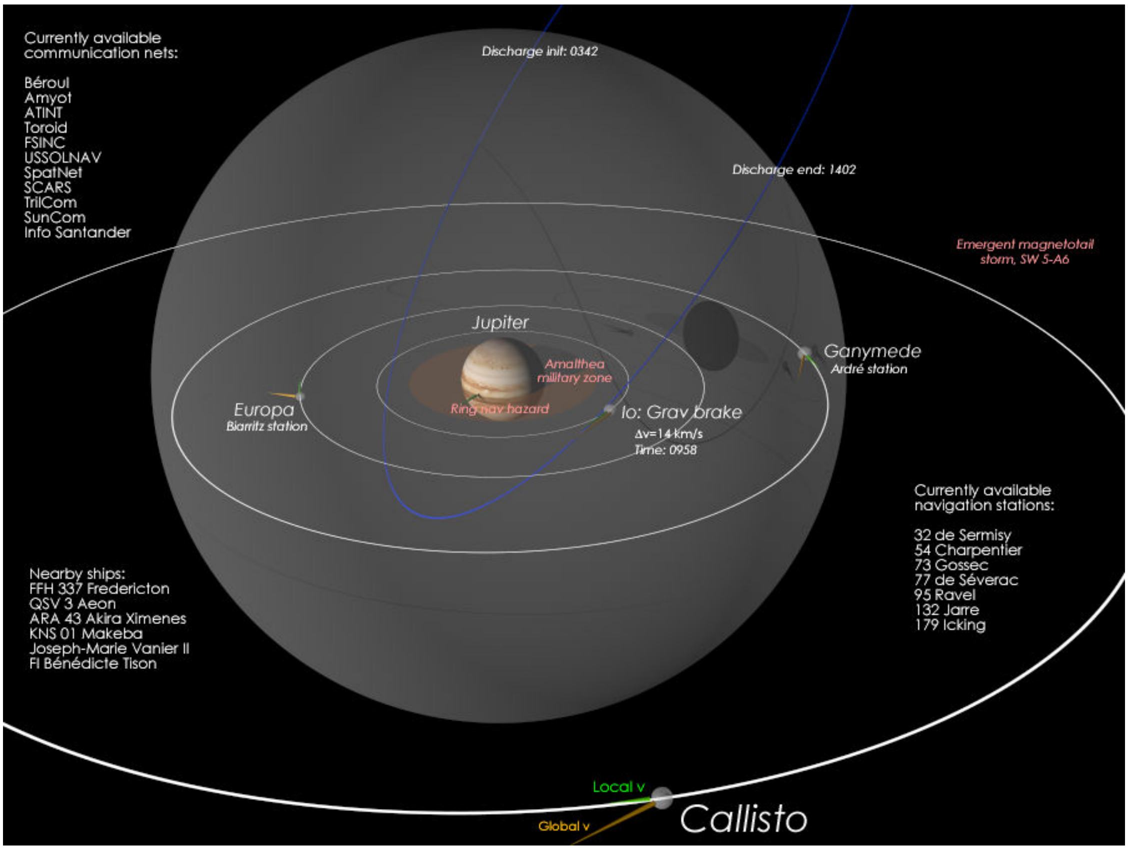
Interstellar Velocity Adjustment



The difference in velocity between stars pose a major problem for starship traffic. The velocity differences are on the order of many tens of kilometres per second and directed in different directions. This means that a ship that leaves Earth at a relatively low real space speed (a few kilometres per second) once it emerges at Barnard's star it will move 140 km/s relative to the system! Going to the more sedate Nyotekundu system induces 55 km/s and Alpha Centauri 31 km/s excess velocity. This is far more than escape velocity for most planets and solar systems, and precludes close orbits to discharge stutterdrives.

Some ships are powerful enough to accelerate enough to overcome this speed difference, but reaction mass costs tend to be high. It is more popular to attempt complex gravity assists or "linear discharge".

A ship passing close to a moon or planet will exchange momentum with it due to the gravitational interaction. This can be used to gain or lose speed depending on direction, giving up to twice the orbital velocity of the planet. While this is often far less than the velocity excess of a newly arrived starship (usually about 30-50 km/s) it is often useful.

The most popular gravity assist targets are cold gas giant inner moons. They are often heavy, move fast (big delta-v), airless (no risk going close) and close to each other for multiple assists. Assists can also be repeated: after passing by, the ship engages the drive and returns for a second pass. This way even a relatively light moon can turn the ship's velocity vector significantly. Another trick is powered assists: using thrusters close to periapsis the velocity change is maximized. Some ships even make use of aerobraking or magbraking, although this is risky.

These multiple passes are often the favourite part of a trip for tourists, as they get to see not only new planets and moons, but for once actually experience some speed - approaching a planet at 100 km/s (ship speed plus the planet's speed) is fast enough to make it a viewable spectacle as the target grows visibly over the span of 20 minutes followed by a dramatic flyby over a few minutes. The number of viewers of the second or third pass tends to be much lower.

It is also common to use a "half slingshot", warping in just to the 0.1g limit and then allowing the planet to reduce speed. An even more radical kind of assist is the "hanging assist", where the ship moves in close to the limit and uses the drive to remain in place while the gravity of the planet decelerates the ship. A limitation is time: at 0.1g it takes 11 days to slow down a 100 km/s ship to zero speed relative to the planet. A similar technique sometimes is used to build up velocity in a desired direction, especially if the next system does not have any handy planets.

Linear discharge means that the ship does not orbit a planet but sweeps past it inside its gravity well. Once it is outside the stutterwarp limit it returns to its insertion point and nearly retraces the orbit. This saves the effort of slowing down, but produces numerous discharge/jump cycles that will keep the drive engineers cursing.

Which method to use depends on a large number of factors. The velocities of different star systems, planets and moons are well documented in navigational databases. As planets and moons orbit their velocities will change. A pilot will try to minimize the total delay due to orbital manoeuvres and travel inside stutterwarp limits, yet also avoid inefficient linear discharges, the risks involved in going too close to planets with atmospheres or radiation belts, as well as the costs of fuel – while ideally getting a new velocity vector that will make entry in the next system convenient. Software for navigational decision support has been around for ages, but it is useless if the pilot cannot decide on what to prioritise.

Some trips are more popular than others due to the relationships between the stars, while other systems are "cumbersome" because of their high velocities. Barnard's Star, Arcturus and Lacaille 9352 are among the worst. Lacaille 9352 is simply avoided by using the Xiuning-Hunjiang route. Barnard's Star is a major headache for shippers along the American and Manchurian arm but absolutely necessary. At any point in time dozens of ships are trying to adjust velocity, giving it the nickname "the Carousel". Arcturus forms a natural threshold, since the high velocity and lack of any planets forces kafers and humans to orbit close to the star – it is impossible to defend, yet impossible to take.

A few systems have velocities that match up, making them much easier to use. There are even "seasonal" velocities: systems that have good discharge planets with velocities that some part of their planetary year makes access handy. For example, the gas giant Yu-Hungdi at Delta Pavonis tends to "align" with D'Artagnon very neatly every 10 years, making traffic much swifter (and reducing the number of ships docking at Han-Shan).

As an example, here are the velocity differences at the core worlds of the French arm. As can be seen, going via Crater is usually more cumbersome than going by Joi. To make matters worse, the

Henry's Star system has no gas giants to make velocity adjustments; just the two stars and Crater itself. Joi on the other hand, is moving slowly relative to Kimanjano, making traffic easier in that direction - especially since both systems have useful gas giants.

	Beta Canum	Joi	Kimanjano	Crater	Kie-Yuma	Nous Voila	Beowulf
Beta Canum	-	42	47	77	-	-	-
Joi		-	17	57	25	-	-
Kimanjano			-	73	-	72	51
Crater				-	82	-	-
Kie-Yuma					-	-	-
Nous Voila						-	-
Beowulf							-

(This is based on real data for BC, Joi, Kie-yuma and Nous Voila, while the data for Kimanjano and Beowulf was generated randomly. Kimanjano has velocity vector [5.7205 8.7013 -28.2881] km/s, Crater [-36.7366 -39.6589 6.3422] and Beowulf [27.6984 -4.0101 15.4959])