GOING DEEP:

EXCALIBUR ALMAZ AND COMMERCIAL FLIGHTS BEYOND EARTH ORBIT

BY CLIFFORD R. MCMURRAY

It all started with an auction.

Art Dula, a lawyer and entrepreneur specializing in space law, had been doing business with the government-owned space firms in the Soviet Union for several years before that country collapsed. As the newly privatized, cash-strapped companies looked around for any possible source of revenue, they gave Dula a call. Dula arranged a "Russian Space History Sale," a first-of-its-kind auction at Sotheby's in December 1993. In the process, he stumbled across some moth-balled spacecraft from the secret Soviet military space station program, named Almaz. He wrote himself a contract that gave him the right to sell this hardware—or fly it. He purchased four Almaz crew capsules, now called reusable re-entry vehicles (RRVs), and two space station core modules of the same basic design that flew as Salyut, Mir, and the ISS Zarya module. The RRVs carry a crew of three, and have been certified for a minimum of 15 flights each. More can be manufactured if demand is great enough.

In 2005, Dula and his partners incorporated Excalibur Almaz (EA) on the Isle of Man. The tiny island, a self-governing crown dependency of Great Britain, might seem a strange place to set up shop, but it's a logical choice. The government has been courting space businesses for many years. Thirty out of the world's 54 commercial satellite companies have a presence there, and its corporate and individual income tax rates are very low. EA moved its spacecraft into storage at a decommissioned Royal Air Force base, and set to work.

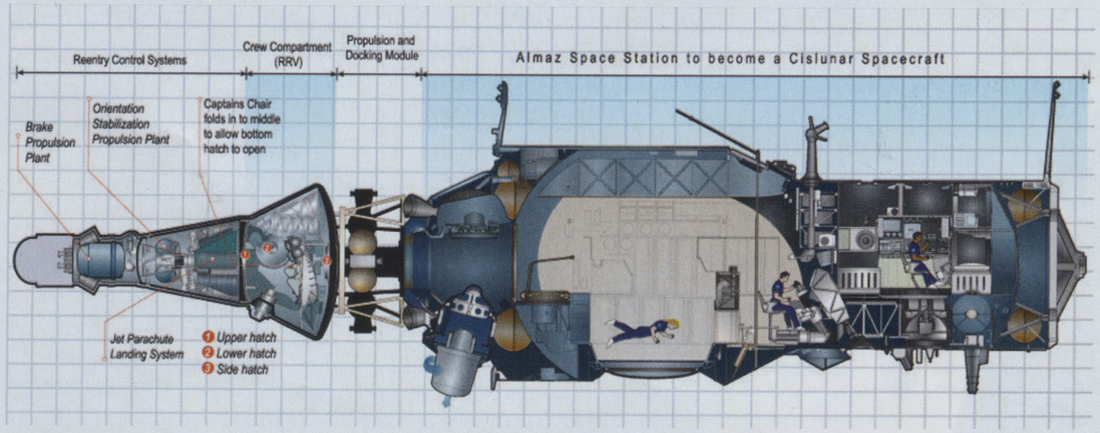
EA spent $46 million over the next seven years, while keeping a low profile. They brought the blueprints for the hardware they had purchased up to current standards, acquired export licenses from Russia and licenses for technology sharing from the U.S. State Department, and paid for four market studies by Futron to identify potential customers. They hired a number of subcontractors, including Almaz manufacturer NPO Mashinostroyenia, United Space Alliance (the company that operated the space shuttle under a NASA contract), and the major European aerospace company Astrium, to perform technical and design studies of how the spacecraft could be used and how much they would cost to operate. Finally, in the spring of 2012, they were ready to tell the world about their commercial space program and start looking for customers—and additional investors.

The Almaz crew capsule looks much like an Apollo capsule, but has a slightly smaller habitable volume for its crew of three.

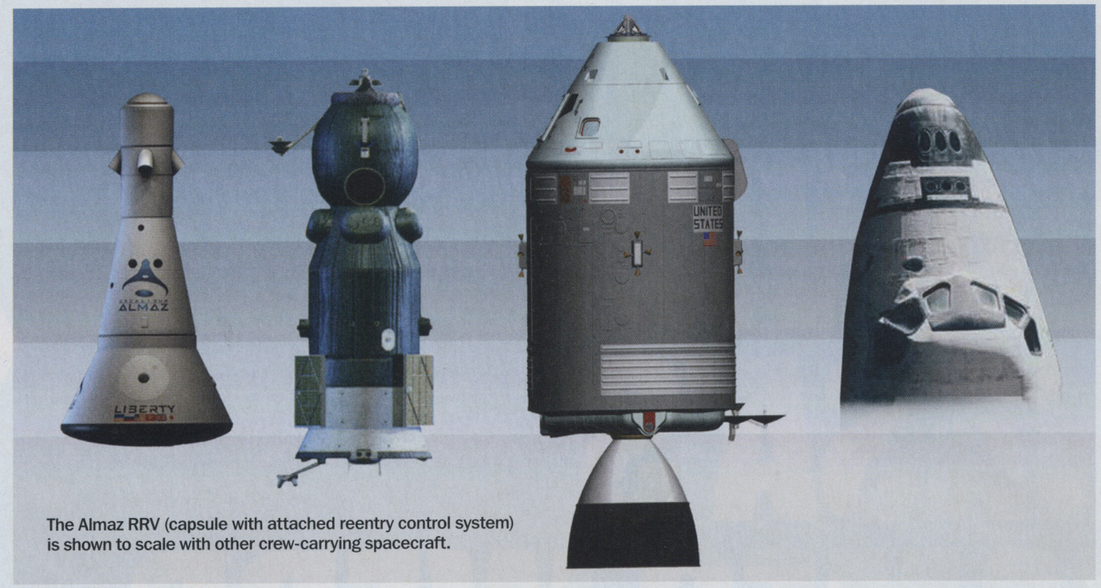
Dula, a member of the NSS Board of Governors, chose the National Space Society's International Space Development Conference, held in Washington, D.C. this May, for his first public presentation. There were many NASA representatives attending the conference, and Dula wanted to see whether there would be any objections to the technical aspects of EA's plans. There were none.

EA is unique among aspiring commercial crew carriers in that all of its hardware is flight-tested. RRVs were flown successfully nine times (one capsule made three flights, another made two flights.) One of those flights was an unplanned test of the launch escape system; the capsule was pulled away from its Proton booster by the abort rockets when the launch vehicle exploded 53 seconds after liftoff. The RRV and its cargo were recovered intact. This makes Almaz the only commercial spacecraft with a flight-qualified abort capability, demonstrated the hard way. Another of the RRV test flights saw it docked to a Salyut space station for 175 days, so its ability to stay in space for long missions is also an established fact. As for the space station modules, similar modules have been supporting human crews in orbit since the early 1970s.

When the RRVs and space station modules fly to space they will, of course, fly with updated avionics and life support hardware inside



The Almaz RRV (capsule with attached reentry control system) is shown docked to the space station module. The crew enters through an access door in the capsule's heat shield.



The Almaz RRV (capsule with attached reentry control system) is shown to scale with other crew-carrying spacecraft.

the pressure vessels. Much of the new hardware will come from EA subcontractor Astrium, the European manufacturer of the Columbus ISS module and the Automated Transfer Vehicle, an unmanned ISS resupply spacecraft. But the flight-critical emergency escape and re-entry systems have been demonstrated in flight, and most of the new systems will also be off-the-shelf equipment at Technical Readiness Level 9, the same level of certification as the space shuttle's components. The new hardware has the added advantage of being smaller and lighter in weight than the vintage fixtures, which leaves more room for payloads.

Using flight-proven equipment gives EA a huge financial leg up on potential competitors who have to develop their vehicles from scratch. At current prices, just buying the nine Proton launches that tested the RRVs would cost about $900 million. And EA is two years and $500 million ahead of SpaceX when it comes to development of an emergency escape system; that's the amount of time and money SpaceX thinks it will cost to qualify the abort system for the Dragon capsule in which it wants to fly paying passengers.

EA's original business plan had envisioned flights in low Earth orbit (LEO), but Futron's market studies produced an unexpected result: The market for flying humans beyond LEO, to the Moon, and even deeper in space was a more profitable market than LEO. Futron projects that over the next decade about 30 paying passengers will pay an average ticket price of $100 million per seat for flights in cislunar space. The passengers might be wealthy (make that very wealthy) private explorers or government-paid astronauts. Who pays for the ticket isn't important as far as Dula is concerned. The point is that tickets can be sold, and EA is now ready to sell them.

The first EA expedition begins with the launch of one of its space stations to LEO. The station will be outfitted with Hall ion engines, which provide a small but continuous thrust at an extremely high exhaust velocity. Again, these engines are off-the-shelf hardware; they've been flown in space 170 times without a single failure. The advantage of ion engines is that they don't use much fuel, but the low thrust means that they take a long time to get the spacecraft moving. Flying to the Moon, a trip which took Apollo astronauts three days, will take about three months for the Almaz space station. The crew, launched separately in one of the RRVs, might dock with the station in LEO and take the slow ride out to the Moon, or they might fly out on a faster, Apollo-style trajectory and meet the station at the Moon. The mission profile has many possible variations, and many decisions, including how long the crew stays in lunar space and whether they ride the station back to LEO or leave it in lunar orbit, that remain to be determined by whoever pays for the trip. But the space stations, with a useful life of 10-15 years, can support many expeditions beyond the first one.

If EA doesn't yet know exactly what its first flight profile will look like, it knows how much money it will charge per crew member. The first tickets will sell for 100 million British pounds each (about $155 million). About $460 million for this flight isn't pocket change. But Michael Bowker, EA's vice president of business development, points out that each of the upcoming ISS resupply missions that SpaceX has contracted to fly for NASA costs about $130 million, and those flights are uncrewed. By comparison, he says, "delivering humans to L2 for $450 million seems like a bargain price to me."

Destinations even farther out are also possible. EA is looking at flights to the L2 Lagrange point, or even flights to a near-Earth asteroid. The first flight can come within three years of signing a contract. Who will be the first paying customer for a ride beyond LEO, and where will they choose to point the prow of their spaceship? We should have an answer very soon.

Clifford McMurray is a former executive vice president of the National Space Society.

THE STORY OF PLANETARY RESOURCES:

HUMANITY'S GREAT ADVENTURE IN THE 21ST CENTURY

The mission of Planetary Resources, the company I co-founded along with Peter Diamandis, can be stated quite simply: Our company aims to bring the solar system within humanity's sphere of influence.

I firmly believe that accessing space resources is absolutely crucial for our future. First of all, the solar system's vast wealth will enable increased prosperity and growth for humanity here on Earth. Second, space resources will sharply reduce the cost and increase the viability of large-scale human space exploration and settlement. For these reasons, when my long-time friend Peter Diamandis and I sat down some time ago and asked ourselves, 'What is the next big step in space?' it became clear to us that the answer is about opening the resources of space for the benefit of humanity. Thus Planetary Resources was born.

To accomplish this audacious goal, Planetary Resources will focus on the near-Earth asteroids (NEAs). To me, asteroids are the low-hanging fruit of the solar system. They are not hindered by sitting in a gravity well and they are easily accessible. Moreover, NEAs are rich with economically interesting materials and elements. As scientists have learned more about asteroids in the past few decades, we've realized they contain the resources that humanity needs to explore space. In fact, the resources effectively contained in the NEAs will prove to be an invaluable asset if humanity is going to one day support large settlements of people on the Moon, Mars, the moons of Jupiter, or beyond.

I firmly believe that the next 20 years are going to be really exciting for those of us who have been working towards and waiting for major advancements in space exploration. It gives Peter and I a lot of hope for the future. Back in the 1990s, when Bob Zubrin was first talking about Mars missions, he made great points about the benefits of a frontier society for human civilization, and the positive impacts of exploration in promoting a vibrant human future—and we agree with that wholeheartedly.

The material wealth of the asteroids is nothing short of staggering. Asteroids exist in the solar system in practically limitless numbers. Almost 10,000 NEAs have been discovered to date and scientists predict that somewhere between half a million to a million exist. So only between one and two percent of the NEAs have been discovered, yet out of the 10,000 we have at our disposal, there are ample resources, water, precious metals, and raw materials to grow a spacefaring society and benefit us on Earth—and these resources are not difficult to access.

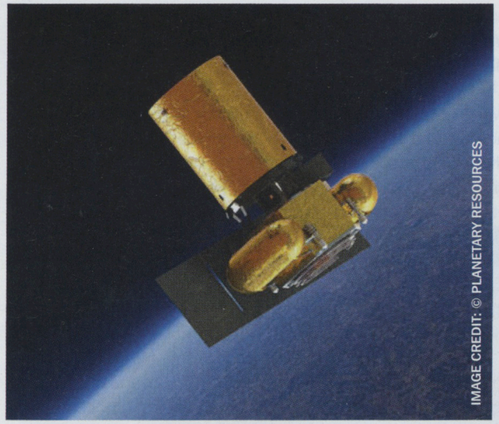
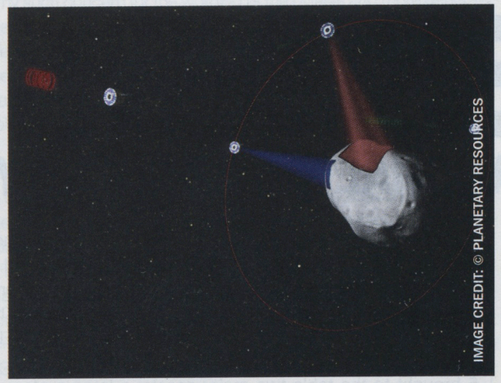


Illustration of Planetary Resources Inc.'s initial spacecraft, the Arkyd-101 space telescope in Earth orbit.

We are very fortunate to have a large collection of asteroid material to study here on Earth, in the form of meteorites. By examining the composition of these objects in laboratories, we have discovered that certain types of meteorites have high platinum group metal (PGM) content. PGMs are rare on Earth, especially because the high atomic weight of these elements meant they sank toward the core of the planet during Earth's early formation. In comparison to their extreme scarcity on Earth, one PGM-rich asteroid could contain more platinum that has ever been mined in all of human history.

In addition to obtaining valuable metals such as platinum, Planetary Resources will also gain access to the most valuable resource for solar system exploration—water. Water can be converted to high-energy rocket propellant: hydrogen and oxygen. As just one example, a 500-meter carbonaceous asteroid with a high concentration of water could be valued at trillions of dollars, given



Planetary Resources is developing the technologies to enable low-cost prospecting of asteroids. Resource extraction from asteroids will deliver multiple benefits to humanity and grow to be valued at tens of billions of dollars annually. The effort will tap into the high concentration of precious metals found on asteroids and provide a sustainable supply to the ever-growing population on Earth.

that the only alternative way to obtain water in space is to launch it at high cost from Earth's gravity well.

Planetary Resources has a series of spacecraft that we are going to use to explore the top NEAs, called the Arkyd series. The Arkyd-100 Series will test out our systems in low Earth orbit and serve as an observation test-bed. The Arkyd-200 Series adds propulsive capabilities, enabling us to reach nearby asteroids. The Arkyd-300 Series adds long-range laser data communications and improved propulsive capabilities, allowing us to prospect asteroids for resources. Multiple Arkyd spacecraft will be deployed, working together in a distributed fashion.

Eventually, a select few asteroids will be chosen for processing. We will first extract water, usable as propellant. Once we have propellant, Planetary Resources will have the ability to easily and affordably deliver materials to the point of need. We will enable the roadways to Mars, to other asteroids, to the Moon, or even to bring back materials to Earth.

Planetary Resources' spacecraft will be dramatically less expensive than previous designs, because we are combining the best of commercial innovation with a rapid development cycle, and we are hiring the best people to our team from within and outside the aerospace industry. Our team is composed of people who are at the top of their fields.

Our vision for the future is completely aligned with the vision of the National Space Society. It is about settling space; it's about having that sustainable presence off-Earth, whether that presence is on Mars, the Moon, or the moons of Jupiter—hopefully all of them—or even on the asteroids themselves. In order to expand our presence in the Solar System and make all this possible, we have to utilize the resources of space. And that is precisely what Planetary Resources is all about.

Eric Anderson is a co-founder and co-chairman of Planetary Resources, Inc., based in Bellevue, Wash.