COMMENTARY Jack Burns

U.S. Vice President Mike Pence, speaking at the U.S. Space and Rocket Center in Huntsville, Alabama, March 26, directed NASA to land humans on the moon by 2024, four years earlier than the agency's current plans.

America is ready to explore

ACCELERATING THE U.S. SPACE PROGRAM REQUIRES MEASURED RISKS. FAILURE IS NOT A FAULT; IT'S AN OPPORTUNITY TO LEARN AND IMPROVE

At the recent National Space Council meeting, U.S. Vice President Pence challenged the nation to begin exploring space again with a human mission to the moon's south pole by 2024.

Public-private-academic partnerships will help us accelerate a new lunar program. Such successful collaborations have already advanced commercial development in low Earth orbit and space science missions that are surveying the solar system and beyond. Coupled with international alliances, we can expand the aerospace pie, open new opportunities for a new generation of engineers and scientists, and develop a true space economy.

America must continue to be a leader, willing to invest real and intellectual capital, to develop a balanced space exploration program. If NASA is to spearhead space exploration, the agency should:

- Demonstrate preeminence in space by swiftly expanding humanity into the solar system, incorporating public-private-academic partnerships and other means that expand American involvement in space exploration and utilization.
- Establish its space science, exploration, and aerospace technology research as second to none.
- Define a clear strategic vision for the development and acceleration of aerospace technologies and knowledge transfer to American firms to spur economic growth and create real jobs at home.
- Support American companies in pursuing the vast economic resources of space and development of a sustainable space economy that supports science and exploration missions.
- Streamline agency operations and maintain a laser focus on missions that maximize the taxpayer's investment in space.

These goals are incorporated into President Donald Trump's Space Policy Directive 1, which calls for NASA to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." But to carry out this visionary program for space exploration, NASA will need adequate resources. Past administrations have had grand ambitions for post-Apollo space exploration, but they ultimately collapsed without sufficient buy-in from Congress and, thus, the funding to succeed. In carrying out the president's SPD-1, our ambitions must be matched by appropriate funding from government, commercial and international sources. We must be realistic in recognizing, as was true with the early airline and computer industries that the federal government will be the anchor tenant

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in the development of cislunar space over at least the next decade. Our investments today will enable entrepreneurs to close their business plans in the future.

The moon is the obvious and practical destination to renew our ambitions for deep space journeys of discovery. However, before we begin, we need to clearly articulate the reasons for going to the moon so Congress and the public will embrace this goal. Pieces of this plan exist but it currently lacks cohesion. We must clearly communicate a bold plan at this juncture with the full participation of taxpayers, Congress, industry and international partners. All are thirsting for leadership by the United States.

The first element of the strategic plan for space exploration has already begun with Commercial Lunar Payload Services (CLPS), a NASA program to provide private-sector transportation to the moon. Nine large to startup-sized companies were recently selected by NASA as potential transportation service providers. Furthermore, NASA selected 12 science and technology payloads in March to fly on these commercial landers. One experiment, on which I collaborate, will carry a radio science payload on a CLPS lander. This project could be the first step in placing an array of low radio-frequency telescopes on the moon's farside—the only radio-quiet environment in the inner solar system.

Such a radio array would search for the magnetic fields that might sustain life around planets orbiting other stars. And it would detect, for the first time, the first generation of stars in the early universe – both priorities of the Astrophysics Decadal Survey. This array could also be deployed by a rover on the moon's farside, teleoperated by astronauts working on NASA's lunar Gateway.

There is much more that robotic missions to the moon should do. Results from NASA's LCROSS impactor mission and India's Chandrayaan-1 point to an abundance of water ice within permanently shadowed craters at the lunar poles. This is a game-changer. Water is the key to sustaining human exploration and economic development on the moon and beyond.

Such water ice can be used to support a human presence on the lunar surface by providing oxygen to breathe, water to grow crops, and protection from solar radiation. Water can also be broken into hydrogen and oxygen, and reassembled as rocket fuel. Manufacturing rocket fuel on the moon, with its much lower surface gravity, could fuel a future cislunar transportation economy. Several private companies have already formed with the goal of mining water on the moon. But, first, we need to determine if we can practically extract this water ice from craters at just 40 degrees above absolute zero. This requires a robotic prospecting expedition to the moon. Such a mission could be formulated using the public-private-academic model to provide the scientific and engineering expertise to harvest this valuable lunar resource. NASA has begun to reformulate the canceled Resource Prospector mission to include a rover and a suite of instruments that will extract samples from a meter below the surface. Before a human mission to the moon's south pole, it is urgent that we launch a robotic mission within the next few years.

In December, the Chinese Chang'e-4 spacecraft was the first to land on the far side of the moon. The moon is tidally locked with the Earth so the farside always faces away from the Earth. The Chang'e-4 mission was made possible by placing a communication satellite in a halo orbit around the Earth-moon L2 Lagrange point about 65,000 kilometers above the farside. This landing was a significant accomplishment for the Chinese space program but it was also a disappointment that NASA was not there first. There is much more to be done on the lunar farside. The South Pole Aitken Basin, where Chang'e-4 landed, is the largest, oldest, and deepest crater in the inner solar system. It holds the key to understanding the history of how both the Earth and moon were bombarded with asteroids billions of years ago, a process that likely reshaped the surfaces of all the terrestrial planets and possibly induced life to form on our home world. After decades of planning by the American planetary science community, it is time for NASA to lead a sample return mission to the South Pole Aitken Basin to collect this invaluable evidence of our planet's beginnings.

A sustainable lunar program must include humans on the surface by the middle of the 2020s, not the end of the decade. This lander would reuse systems and technology from the years of investment in America's deep space spacecraft, including Orion, Curiosity and InSight, coupled with elements from the robust and growing commercial industry. Such an approach logically begins with what we have now and would incrementally increase the nation's capability for ever more extensive human-robotic exploration by infusing new technologies and ideas over time. This approach will bypass historic delays in completing new human missions. Indeed, the Apollo Applications Program of the 1970s had this concept at its core. It provided stunning achievements, such as Skylab and Apollo-Soyuz, and conceived of bolder applications leading to a dual flyby of Venus and Mars – a bridge to the needed technological advances for Mars landings. We should pay attention to this lesson from history and do likewise.

If this strategic vision for lunar development is to succeed, there must be a change in our tolerance for risk. As we all know, space is a difficult, demanding, and dangerous environment for humans and machines. But, as was true in the days of Apollo, we need to take measured risks to accelerate America's space program — to explore, to discover and to invent a cislunar economy. This will require a culture change where failure is not a fault but rather an opportunity to learn and improve, as is true in all entrepreneurial organizations. Equally important is stability of national leadership and our goals for the space program where long-term objectives and proper funding are maintained giving us all the best opportunity to succeed. **SN**

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