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Irrational!

by Dan Duda (From *Penn Central*, June 2015, used by permission)

There's something strange about Pi. Really strange. Irrational even. Remember those geometry and trigonometry classes that bored you silly in high school? There may have been something not only interesting, but very mysterious hiding in those droning lectures and the endless parade of formulas that had you counting the minutes till the lunchtime bell. How much of the lecture focused on the issue of "irrational numbers"? If you were like me, the "irrational" part was the fact that you had to wait another half hour for the bell to save you.

But perhaps you were stirred, maybe a little, to think about the real meaning of an Irrational number. They can't be completely resolved by a fraction or a decimal. Their true character goes on forever, into infinity. In a sense they don't totally exist in our limited reality. In an attempt to avoid the boredom mentioned in previous paragraphs, I'll refrain from listing all the incidences where an irrational number, like Pi, steps in to save the day for what would otherwise be a mathematical dead end. But, you need to know that it's deeply involved in issues like the famous Fibonacci sequence, which frequently and mysteriously pops up in nature, and even the Bell Curve that's essential to so many scientific analyses, including statistics and quantum mathematics.

OK, let's focus on just one of the major enigmas science currently faces that may relate to "irrational" numbers—gravity. From Galileo to Newton to Einstein the true nature of gravity has not been revealed. Galileo and the Tower of Pisa experiment did begin to open our minds to the nature of this force, but it was just a start. Newton broke new barriers putting gravity onto the list of legitimate scientific and mathematical studies, but he didn't even hazard a guess as to what it really is.

Einstein blew our minds in defining in much more precise detail how gravity works as well as providing an explanation about what it is (i.e., a bending of time and space). But that still leaves science confused—why is gravity so weak? Why does it resist all attempts to enfold it into quantum mathematics and help resolve its conflict with Einstein's Relativity? Where is the 'prodigal son' of the Standard Model of particle physics—the graviton?

[Caveat Lector] Math is considered the rock solid foundation of science—its lever. In fact, some now believe that reality at its core is math and nothing else, but it does contain riddles, and Pi (along with the field of irrational numbers) is the fulcrum that both exemplifies the fantastic reach of this incredible tool, as well as point to some of its apparent enigmas. Think about the fact that a circle or a sphere (or any curved object) requires the irrational Pi to complete its mathematical description. That means that anything containing curves is mathematically incomplete within our reality. Could that prove that there are dimensions or even universes beyond what we experience directly?

The idea of a many-dimensional "multiverse" contained in "M-Theory" has become an accepted topic of serious scientific discussion. In that theory, the description of gravity as consisting of closed loop strings, unattached to the 'brane' of our 3-dimensional world, means that they are free to migrate out of our reality.

Well, you decide. Is there something really mysterious about Pi and other irrational numbers? Or do you feel 'it's just math, don't think about it so much'? In my mind, it's a flashing neon sign pointing to an existence beyond our common sense and experience. Possibly a majority of what "is" lies well beyond our current ability to comprehend. In the words of theoretical physicist Brian Greene, "One of the strangest features of string theory is that it requires more than the three spatial dimensions that we see directly in the world around us. That sounds like science fiction, but it is an indisputable outcome of the mathematics of string theory."

Ask Dr. SETI ®

Following Up on Past Detections

Dear Dr. SETI:

*I see from your website that Project Argus has plateaued at ~150 telescopes, and has switched to a strategy of intermittently scanning the whole sky. There have been a number of signals of apparently extraterrestrial origin that have lasted a brief time and never been seen again. The WOW! signal, at 30 sigmas, is the standard for Project Argus. The 2010 signal from TYC 1220-91-1, a solar twin older than the sun, was at 300 sigmas IIRC and at Pi * 1420 MHz. Carl Sagan, in PALE BLUE DOT, mentions 11 such signals and that was about 20 years ago.*

Benford has argued well that the best strategy for contacting another planetary system is to scan the Milky Way with a narrow beam, or sending quick bursts to nearby likely stars at high power. Such Benford Beacons would give such short bursts at long repetition periods, Would it be possible to devote some of the Project Argus telescopes to monitor the strongest signal locations continuously, so we can get a repetition period and confirm them?

Anonymous, via email

The Doctor Responds:

You raise some important questions about follow-up detection and signal verification. Unfortunately, the answer is not a simple one.

First off, the validity of the very kind of ongoing monitoring of known coordinates of past detections is widely recognized, and such activities are vigorously pursued. The coordinates of the Ohio State University "Wow!" signal, for example, are probably the most widely observed of any in the sky. Thousands of hours of observation have been conducted over the past 37 years, from all of the world's great radio telescopes (I was privileged to conduct one such set of observations myself, from NRAO Green Bank WV). They have all come up empty, but that does not invalidate the follow-up monitoring strategy.

The two most widely practiced SETI search strategies are the all-sky survey and the targeted search. They are compared and contrasted in this brief article:

http://www.setileague.org/general/whatsurv.htm

The two strategies require different instrumentation designs. An all-sky survey is best conducted with relatively small, low-gain antennas, which exhibit a wide angular beamwidth, maximizing sky coverage. They tend to be fixed in orientation, operating in drift scan, or meridian-transit, mode.

Targeted searches require much larger, higher gain antennas with incredibly narrow beamwidths, which are operated in tracking mode to remain fixed upon a single set of celestial coordinates as the Earth rotates on its axis. Since the kind of follow-up activity you suggest is in effect a targeted search, it is best performed with instrumentation of the latter type.

Since Project Argus was designed as an all-sky survey, its stations are of the former design, optimized for drift-scan use, and thus not well suited to the activity which you propose. But, all is not lost.

Probably the best instruments currently in existence for long-term follow-up monitoring of past known sources are the 42 dishes of the Allen Telescope Array, aimed either individually or collectively. These larger, higher-gain antennas are narrow-beamwidth, fully steerable for continuous tracking, and have feed designs and receivers which are sufficiently frequency-agile to concentrate on the specific portion of the spectrum at which a given candidate signal was initially detected. And, in fact, the SETI Institute has been devoting a portion of the ATA's operating schedule to conducting the very kind of activity, and using the very targets, you have suggested! So, your idea certainly has merit.

As for Project Argus, its meridian-transit instruments will continue to scan the skies for other intermittent but interesting candidate signals. You can be sure that any found will warrant follow-up observations from the ATA and other such targeted-search instruments.

Power Measurements with a Spectrometer

Dear Dr. SETI:

I have a SpectraCyber receiver, and am using it with your Horn of Plenty antenna design, to learn the basics as I build up my understanding before I launch into a larger antenna with greater range (reach into the cosmos). I have been befuddled with *the SpectraCyber's output . It took me quite a while to discover that the voltage output was not proportional to power but that the IF gain setting was apparently proportional to power. I think it is because of the existence of a "baseline" voltage that comes from the square-law detector upon which rides the signal from the antenna which includes of course LNA noise, spillover, cable noise etc.*

I find that I need the absolute value of some voltage which cannot be gotten from the IF gain setting. The variation of the "baseline" with temperature just adds another undesirable variable. I would like a system that gives me a Signal = constant (POWER) rather that Signal = constant (POWER + B) where B=baseline. Is this possible?

James, SETI League member

The Doctor Responds:

As you probably already know, James, radio telescopes typically operate in one of three modes: radiometer, spectrometer, or interferometer. Each has a distinct purpose and design strategy. A radiometer measures (and is calibrated for) the total incident power collected within its design bandwidth. A spectrometer displays (and compares the amplitude of) multiple frequency bins within its bandwidth. And an interferometer uses interference patterns between multiple antennas to increase spatial resolution, independent of amplitude calibration.

I think part of your confusion has to do with the fact that the Spectra Cyber is a spectrometer, not a radiometer. Thus, it was never intended to provide absolute (calibrated) power measurements. It should, however, be possible to determine the difference (in dB) between various spectral components. If you have a good hot source (say, the Earth, at an estimated 290 K) and an equally good cold source (say, the Northern sky, estimated at around 10 K), then you can use their indications to crudely calibrate your system to interpolate the noise temperature of objects in between those figures. You can pretty much ignore antenna temperature, since a horn (unlike a dish) does not exhibit spill-over, and is neither over- nor under-illuminated. But, unless the detector is operated in the middle of its square law region, and the signal strength variations are small, this will result in merely relative, not absolute, measurements. After all, a spectrometer is not a (much more expensive) calibrated radiometer! ❖

Event Horizon

SearchLites readers are apprised of the following conferences and meetings at which SETI-related information will be presented. League members are invited to check our World Wide Web site (www.setileague.org) under *Event Horizon*, or email to us at info@setileague.org, to obtain further details. Members are also encouraged to send in information about upcoming events of which we may be unaware.

October 12 - 16, 2015: *66th International Astronautical Congress*, Jerusalem, Israel.
February 11 - 15, 2016: *AAAS Annual Meeting*, Washington, DC.
April 16, 2016, 0000 UTC - 2359 UTC:: Sixteenth annual SETI League *Ham Radio QSO Party*: 3.551, 7.0309, 7.2039, 14.084, 14.204, 21.306, and 28.408 MHz.
April 17, 2016, 1300 EDT: Twenty Second SETI League *Annual Membership Meeting*, Little Ferry NJ.
May 27 - 30, 2016: Balticon 50, Baltimore, MD.
August 17 - 21, 2016: *MidAmeriCon II*, the 74th World Science Fiction Convention. Kansas City, MO.
September 26 - 30, 2016: *67th International Astronautical Congress*, Guadalajara, Mexico.
April 15, 2017, 0000 UTC - 2359 UTC:: Seventeenth annual SETI League Ham Radio *QSO Party*: 3.551, 7.0309, 7.2039, 14.084, 14.204, 21.306, and 28.408 MHz.
April 16, 2017, 1300 EDT: Twenty Third SETI League *Annual Membership Meeting*, Little Ferry, NJ.
September 25 - 29, 2017: *68th International Astronautical Congress*, Adelaide, Australia. ❖

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Guest Editorials: Knowable and Unknowable

by Michael A.G. Michaud

from the *Centauri Dreams* blog, used by permission

INTRODUCTION

For centuries, many humans have believed that life and intelligence arise on other worlds. We have repeatedly anticipated their discovery, hoping to find them on the Moon, on the other planets of our solar system, and now on planets orbiting other stars.

More than a century ago, a few astronomers observing Mars at the limits of their instruments perceived lines on the Martian surface. Some came to an erroneous conclusion that they were channels or canals constructed by intelligent beings. A newer technology, robotic spacecraft, revealed in the 1960s that the canals did not exist outside the observers' imaginations.

Some things are not only unknown; they may be unknowable with the scientific means available to us at the time. That has led some very intelligent people to conclude that such things can never be known. French philosopher Auguste Comte declared in 1842 that, although we may learn the forms, distances, sizes and motions of stars, we can never know their chemical composition. Yet Fraunhofer already had discovered dark lines in the Sun's spectrum by an early form of the spectroscopy that later revealed the chemistry of astronomical objects. What seems unknowable now may become knowable later.

SETI

Before 1959, most astronomers would have said that detecting signals from technological civilizations at interstellar distances was impossible. Cocconi and Morrison pointed out that the means had come into our hands in the form of radio astronomy. What had been unknowable became knowable through scientific and technological advance. That inspired a Search for Extraterrestrial Intelligence that seeks evidence of extraterrestrial technology in the form of radio signals. What may be the least likely from of alien biology – a transmitting intelligence –seemed the easiest to detect with the means we had at that time.

After 55 years of intermittent searches, or about two human generations, we now have the perspective to treat SETI as an historical phenomenon. There have been well over one hundred search programs. Searches have been broadened beyond radio signals to visible regions of the spectrum and to the infrared, notably to seek emissions from Dyson spheres. This effort has constrained some dimensions of search strategy, such as the probability of beacons. Yet there has been no confirmed detection.

There are many potential explanations for SETI's lack of success. Here I will mention only one, voiced by SETI pioneer Frank Drake: Radio and visual spectrum transmissions may be temporary artifacts of technological intelligence. There might be only a narrow window of time in the development of technological civilizations when noisy electromagnetic signals are generated in large amounts.

Those scientists who have dedicated much of their careers to SETI deserve respect for maintaining scientific standards as they sought to achieve a very difficult goal. Yet, after half a century, it is easy to become discouraged about SETI. We can hope that new observing capabilities like the Square Kilometer Array will make some form of detection more likely, but there is no guarantee of success. The lack of a confirmed finding could lead to a false negative, reflecting the limitations of our technologies, our search strategies, and our assumptions.

Civilizations more technologically advanced than ours might be invisible to our present means of searching. Compressed digital data may be indistinguishable from random noise. Arthur Clarke famously said that any sufficiently advanced technology would be indistinguishable from magic. What if a very advanced technology is indistinguishable from nature?

SETI Institute astronomer Seth Shostak was quoted as saying in 2011 that "If this experiment has merit, it's going to succeed within two or three decades. If it doesn't, then there's something fundamentally wrong with our assumptions." Shostak also has written that our own developmental trajectory suggests that, shortly after inventing technology capable of interstellar communication, a society also develops artificial intelligence. If so, AI may constitute the majority of the sentience in the cosmos. Consequently, looking for signals from habitable planets could be the wrong approach for SETI.

Eventual success still may be possible, though it might require a broader strategy and technical means not yet available to us. The existence of alien civilizations can not be disproved.

WHY DO WE SEARCH?

Why do we seek distant intelligence, even in the face of repeated failure? Is SETI just an extension of normal science? I suggested in 1993 that we search for communicating civilizations in the hope that contact with intelligent others will introduce new and hopefully positive factors into human affairs. (8) The discovery of extraterrestrial intelligence would involve much more than science, raising important philosophical and societal questions.

Even without a discovery, the search has inspired creative thought. As the SETI literature has grown and diversified, we have seen many proposed scenarios of discovery, and many different predictions of what contact might bring. What was once an exotic, small-scale scientific enterprise has led to a vast, multidisciplinary thought experiment about the nature and behavior of intelligence, both on and beyond the Earth.

The prospect of interacting with an alien intelligence has stimulated both hopes and fears; predictions of the consequences have ranged from utopian to apocalyptic. Some authors have imagined extraterrestrials as noble, altruistic philosopher-kings who will help us to solve our problems. Others have imagined ruthless alien invaders who will enslave or destroy us.

These are exaggerations of our own behaviors, at our best and at our worst. It is time to escape Hollywood, particularly the tiresome invasion scenario. Astronomers Ivan Almar and Jill Tarter proposed a scale to categorize the impact of contact. Shostak gave us hypothetical examples based on that scale, ranging from benign to disastrous. He later published a fictional story which ended with the Earth's atmosphere bursting into flame.

ACTIVE SETI

That brings me to the debate about Active SETI, also known as Messaging to Extraterrestrial Intelligence. METI advocates wish to send unusually powerful targeted signals to alert other technological civilizations to our existence in the hope of stimulating a response.

It is easy to understand the frustration of those who have devoted their working lives to discovering signals generated by alien beings. But METI is not physical or biological science. It is an attempt to provoke a reaction from a technological civilization whose capabilities and intentions are not known to us. That reminds us that a factor is missing from the Drake Equation, a factor almost impossible to quantify: alien motivations. Intelligent beings can make choices and take actions. We cannot assume that their actions will be ones that we prefer. Our assumptions about alien behavior have not passed the empirical test.

METI advocates assume there could not be any negative consequences from contact, for two reasons. First, more technologically advanced extraterrestrials are benign, an unproven assumption. Chinese science fiction writer Cixin Liu put it this way:

> On Earth, humankind can step onto another continent and, without a thought, destroy the kindred civilizations found there through warfare and disease. But when they gaze up at the stars, they turn sentimental and believe that if extraterrestrial intelligences exist, they must be civilizations bound by universal, noble, moral sentiments, as if cherishing and loving different forms of life are parts of a self-evident universal code of conduct.

Second, METI advocates assume that interstellar flight by robotic spacecraft is impossible. We humans already have reached all the planetary bodies in our own solar system through such spacecraft, a feat that many considered impossible as late as the 1950s. Some of our machines have left our solar system. There already exists an extensive scientific and engineering literature on interstellar probes, frequently reported on the Centauri Dreams blog. Before dismissing interstellar flight by machines on the basis of its cost to us, we should try to estimate its feasibility for a civilization much more technologically advanced than our own.

Consider an example from our own history. Humans began populating the Americas about 17,000 years ago. For thousands of years, after the land bridge closed, oceans insulated newly indigenous Americans from the peoples of other continents. Technological advance, in the form of reliable ocean-going ships and gunpowder weapons, made them vulnerable. The growing credibility of direct contact by uninhabited machines requires us to widen the range of possible consequences. Whatever the consequences of calling attention to ourselves might be, our descendants will not be able to opt out of them. Prudence suggests that we should conduct a global conversation on this issue before we embark on a sustained program of broadcasting our presence with more powerful transmissions.

Almar proposed what he called the San Marino scale, intended to quantify the potential hazard of transmissions. The main factors are the signal strength in relation to Earth's natural background radiation, and characteristics of the transmission such as direction and duration.

One approach would be to set quantitative thresholds for the proposed signals, such as the normal power, duration, and directionality of pulses from military and planetary radars. Above that level, transmissions would require approval from the organizations that fund, control, or regulate the largest radars and transmitting radio telescopes. Radio telescopes capable of transmitting powerful signals to distant stars have been funded by taxpayers, making their use a legitimate subject for governmental policy decisions.

A discussion, perhaps within the United Nations, could lead to an agreed statement of international policy on such transmissions. We already have seen successful examples of this procedure in space debris and in planetary defense against asteroid impacts. We could shift the debate to a more positive agenda. Expanding SETI beyond the microwave window could be more productive than sending our own signals. An editorial in Nature in 2009 put it this way: "Will we want to beam messages to those other Earths? That question is not resolved. But we should at least listen. Humankind may decide that it does not want to open its mouth, but it would be foolish to cover its ears."

EXTRASOLAR PLANETS

The discovery of planets in orbit around other stars is changing the game. We should recall that some astronomers had been skeptical, even dismissive, of the idea that such planets existed. Finding many extrasolar planets—including some that may be near analogs of the Earth—enables us to begin filling in the suitable planet factor in the Drake Equation. On this point, the SETI optimists were largely right. Thanks to technological advance and clever people, we soon may be able to search for what is likely to be far more widespread than transmitting civilizations: evidence of biology. What once was considered unknowable again is becoming knowable.

Searching for evidence of life with powerful new observing technologies coming on line in the next decade may have a higher probability of success than searching for signals from ETI. Finding a form of biology on one of those planets would give us a second data point for the life factor in the Drake equation, a second L. Some believe that discovering alien life is just a matter of time, effort, and improving technology. NASA's Chief Scientist was quoted as saying that we're going to have strong indications of life beyond Earth within a decade, and definitive evidence within 20 to 30 years.

That optimism is admirable. Yet the nagging voice of history suggests caution. We might recall older mistakes, such as interpreting the periodic darkening of the Martian surface as evidence of the seasonal spread of plant life.

At the same time, we should beware of false negatives due to the limitations of our equipment and our search strategies. Once again, we are observing at the limits of our technologies. A false negative might reflect our assumptions about extrasolar biology, which may be very different from the biology we know on Earth.

There also could be false positives, or evidence that is inconclusive or disputed. The Mars Rock controversy of 1996 may be a preview of what will happen. We are on the fringes of knowability, the time when observations are most likely to lead to ambiguous results.

Before astronomers began finding planets around other stars, our model of planetary systems was based on the one example we knew—our own solar system. Now we know that our case is not typical. Is that also true of biology, intelligence, and behavior? Our models of extrasolar life and intelligence, usually inspired by Earthly examples, may prove to be exceptions to galactic general rules. We may be underestimating how alien the products of utterly different evolutions could be. No one anticipated the strange creatures that scientists first found around Pacific sea floor vents in 1977. The search for extrasolar life will spark new thought experiments about the nature of very different evolutions.

Those who seek life on distant planets may be wise to remember the SETI experience. Like the search for signals, the search for extrasolar life may be more difficult than its most optimistic supporters/advocates foresee. Our expectations may exceed the grasp of science as we know it today. Yet a failure to detect such life would not prove the absence of life elsewhere.

While discovering simpler forms of life would be fascinating for scientists, non-intelligent life will inspire less public interest than alien intelligence. Such life can not grant us wisdom, nor can it threaten us. Emotional debates about the possible consequences of contact—our hopes and our fears– may fade. The SETI experience tells us that there is no guarantee of success. Yet the search is likely to continue, in one form or another.

THE SECOND I

Detecting a habitable world, or extraterrestrial life, could inspire greater optimism about finding ETI by making the existence of alien intelligence seem more probable. Could studies of extrasolar planets reveal evidence of a technological civilization? Some suggest that evidence of certain chemicals in exoplanet atmospheres may imply energy consumption or waste products of industry. But fuel burning and waste-generating industry may be temporary phenomena in a planet's history.

Observations might miss non-technological intelligence, or intelligence that employs technologies that we cannot detect or that are unknown to us. The discovery of an alien civilization may not mean communication with it; there could be contact without communication. What we are looking for is not a dialogue of centuries, but an existence proof.

A failure to find evidence of intelligence could discourage those who hope for inspiration or assistance from outside. We may never receive guidance from distant stars, leaving us responsible for our own fate. That could help revive the anthropocentrism that SETI has challenged for half a century.

Even if sapient aliens exist elsewhere in the galaxy, our inability to find them with existing technologies could leave us effectively alone. The scientific paradigm of Earth's uniqueness as the abode of life and intelligence has not yet been broken.

Finding ETI may be a multi-generational task. Discovery may require rigorous and repetitive searching and data analysis that last beyond individual human lifetimes. It may require a broader strategy, and a willingness to look in new places. It may require technical means not yet available to us.

TRANSITION

We are in a transitional period. While both SETI and the search for life on extrasolar planets will go on, we are seeing an implicit shift of emphasis from seeking deliberate signals of technological intelligence to searching for evidence of life, which may be much more common.

A major factor in this shift is the vast disproportion in resources. The science of planet-hunting is funded much more generously than the science of seeking signals from other technological civilizations. SETI scientists can only dream of a taxpayer-funded capability equivalent to the Kepler telescope. Planet hunters hope to make use of several powerful new instruments (James Webb Space Telescope, Thirty Meter Telescope, Giant Magellan Telescope, European Very Large Telescope, Transiting Exoplanet Survey Satellite). But detecting Earth's twin may have to wait a decade or two.

Ultimately, we may need interstellar probes for closer observation of potential life-bearing planets. Except for our Moon, all of our explorations in our solar system have been conducted by machines, not by inhabited spacecraft. That is even more likely at the interstellar scale.

In the long run, our own interstellar probes could lead to a role reversal. If they are detected by intelligent aliens, the impact of contact might flow from us to them.

EXPANSION

There is another idea implicit in finding and characterizing distant worlds: some might be seen as future homes for our descendants. The theme of human expansion, so prominent in spaceflight literature, may be revived. As Paul Gilster put it, finding a habitable world within twenty light years, coupled with a failure of SETI, would be a powerful boost in building an interstellar consensus. The ambition to travel to those distant worlds, and to convert them to human use, could generate a paradigm that we might call anthropocentrism with a goal.

Statistically, the nearest non-transiting habitable zone Earth-size planet may be within 23 light years. One can envision a hundred year robotic mission to the star hosting such a planet; one human generation might start the project knowing that future generations would finish it.

Encouraging early work on interstellar probes is a small but necessary contribution. I hope that the new Nexus for Exoplanet System Science will reach out to those doing serious scientific and engineering work on interstellar flight by machines.

We may never find alien intelligences out there, but someday we may find extraterrestrial intelligences descended from us. What seems impossible now may become possible later.

Yet there is nothing inevitable about interstellar exploration. It has to be chosen as a course of action, and funded. We cannot foresee all the threats or opportunities that could motivate such ventures, nor can we be sure that those motivations will be enough to make starflight a necessary task for near future human generations.

If interstellar flight is possible, why don't we see them? Even if technological civilizations have the scientific and technological knowledge to launch interstellar probes, they may not do so. Expansion could fail if technological societies are unable to agree on a course of action. They may suffer failures of perception, failures of imagination, failures of nerve, or failures of politics.

WHO WILL LEAD?

What nation, or which people, will lead this effort? In the near term, the United States will remain the biggest player in space, with the world's largest and most diverse programs. But American elites lack consensus about where to go, or when. They are turning away from shared visionary goals that would require us to amass public resources for long-term, large scale non-commercial projects like interstellar exploration or eventual human expansion.

In 1989, as the Cold War was ending, Francis Fukuyama wrote that the worldwide ideological struggle that brought forth daring, courage, imagination, and idealism will be replaced by economic calculation, the endless solving of technical problems, environmental concerns, and the satisfaction of sophisticated consumer demands.

A society whose elites are preoccupied with immediate gratification will not support the vision of human expansion. Some pessimists have suggested that the age of manned spaceflight may be coming to a close. Others express nostalgia for an age of exploration that ended with the mission to Pluto. Analysts predict that China will become the world's largest economy less than fifteen years from now. China's space program is newer and smaller than its American counterpart, but it is growing. China is on the rise, with a determination to succeed in great societal endeavors and an authoritarian political system which makes that possible.

History is not about immutable fate. It is about the choices that humans make.

I end with a quotation from another non-scientist, William Shakespeare:

> There is a tide in the affairs of men Which, taken at the flood, leads on to fortune… On such a full sea are we now afloat: And we must take the current when it serves, Or lose our ventures.

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