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MANNED MARS MISSION ECONOMICS: CONTEXT, PERSPECTIVE, AND PUBLIC PERCEPTION

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ABSTRACT

The American public perceives that space exploration is an expensive endeavor. This opinion is constantly reinforced by the news media and is reflected in several recent public opinion surveys. In particular, a manned exploration mission to Mars is deemed to be vastly expensive. After a proper context and perspective are established, however, a different picture emerges.

This paper will baseline a plausible level of investment required to conduct a robust, manned Mars exploration mission. The author will then establish a proper context for this level of investment, focusing on both primary funding-source domains: public (American taxpayer dollars) and private (corporate or individual benefactors). "Take-Home Points" will briefly encapsulate key concepts.

MESSAGE FROM THE AUTHOR

You are about to read version 2 of this paper, dated October, 2004. I conducted the basic research for the first version in July, 2003 and presented the paper at the annual Mars Society conference in Eugene, Oregon (August, 2003). Since economic statistics are constantly changing, most of the facts and figures were updated for version 2. I have omitted a cost-benefit analysis section of the Apollo program and included a much stronger conclusion section based upon a public opinion survey in July of 2004.

Though I have compiled numerous high-profile cost/benefit analyses in my 20 years of corporate research experience, I am definitely *not* a professional economist or public relations expert. Some of my analytical techniques are rather simplistic and could undoubtedly be improved upon by professionals in these fields. Also, I do not attempt to quantify the highly subjective "benefit" side of the equation, as would be required in any official cost/benefit study. Rather than providing the end-all guide to manned spaceflight economics, this paper is intended to pose specific questions and challenge the reader's basic assumptions. I invite feedback and encourage detailed studies from greater subject-matter experts.

The data within was compiled exclusively from reliable sources. Copies of the references are available to the public over the internet. I ask you, dear reader, to conduct your own research and formulate your own opinions.

To international readers, I apologize for the America-centric nature of this paper. The American government and corporate business environment are used as models. Due to the simplicity of my analysis methods, however, a similar study could easily be performed for any other space-faring nation or allied group of nations.

AMERICAN PUBLIC PERCEPTION (AUGUST, 2004)

The Apollo program deeply affected the psyche of the American public in the 1960's. While most of the intangible effects were highly beneficial (inspiration, motivation, etc), Apollo also gave birth to some lingering errors in perception. Like the benefits, these errors have persisted through to present times.

The most destructive perceptual error is the high cost of space exploration relative to other public-sector expenses. Roots of the problem are difficult to trace and highly speculative, but the media often reinforces this error. Sometimes, the reinforcement is deliberate. An early beneficiary of this perceptual error was the United States government.

In the early 1970's, the Nixon administration partially justified canceling the Apollo program on the grounds that space exploration was Too Expensive. The Apollo budget was redirected toward social programs that had suffered from perceived budget cuts precipitated by the huge, escalating cost of fighting a war in Southeast Asia. Despite the hushed fact that the entire budget for the Apollo program in 1971 was less than one billion dollars - petty cash compared to military or social program expenditures at the time - the misdirection was amazingly effective. The space program ended up bearing a shameful mantle of costliness, rather than the unpopular war effort.

Take-Home Point: As reported to the public, space investments often lack a proper context.

Though the war effort eventually collapsed anyway, the perception of costly space expenditures endures. This perception rears its ugly head whenever any ambitious space exploration project is proposed.

In a public opinion survey for the Associated Press (AP) in July, 2003, 75% of the respondents endorsed the space program as a "good investment."¹ However, only 49% supported the manned exploration of Mars (42% were opposed). A direct quote from a retired respondent in New Jersey bears witness to the current perception that Mars exploration, in particular, is Too Expensive:

"We can go there after all the things wrong on Earth are fixed. I'm totally against any of it. It's a total waste of money we need for our kids, for illnesses, could put somebody's kids through college, could cure so many diseases."

Other public opinion surveys have revealed similar perceptions. In a Zogby research poll, also in July of 2003, 59% of the respondents believed that humans will set foot upon Mars within 25 years – and 18% believed it will happen within 10 years!² However, 24% of the respondents wanted the U.S. to end its manned space program altogether.

Superficially, the Zogby results seem quite optimistic. However, the results for the second question reveal a significant bias amongst the sampling population:

Question 2: What percentage of the federal budget do you think is spent each year on the nation's manned and unmanned space programs?

Figure 1 contains the results of the survey question. Cumulatively, at least 36% of the American public believes the manned and unmanned space program investments are over 5% of the federal budget, with at least 73% believing the investments are over 1% of the federal budget. Since the correct answer to the second survey question is 0.7%, i.e. less than 1%, at least 73% of the American public has a faulty perception of the relative level of space exploration funding. This perception was not corrected within the survey, so a hefty bias must be assumed within the remaining survey answers.

Take-Home Point: Be wary of biased survey questions!

Other biases have plagued past public opinion surveys, sometimes blatantly. In the first question of an Associated Press survey³ in January, 2004, half of the respondents were asked:

As you may have heard, the Bush administration is considering expanding the space program by building a permanent space station on the Moon with a plan to eventually send astronauts to Mars. Considering all the potential costs and benefits, do you favor expanding the space program this way or do you oppose it?

Only 43% of the respondents agreed with this statement, while 52% were opposed. The other half of the respondents were asked the same question but with "United States" substituted for "Bush administration," leading to a 48% split in the results. The attempt to tie political affiliation directly to the survey results, an interesting data-gathering approach, also significantly biased the results of this question and all later questions for half of the responding population.

However, a far worse bias permeated this same survey question. The survey was conducted a week *before* the official announcement of the new Vision for Space Exploration (VSE) by President Bush on January 17th, 2004. Paul Recer, an AP reporter, had previously triggered a wide-spread, persistent rumor in the news media that the cost of the new vision would be one trillion dollars.^{4 5} Several direct references to this groundless rumor in the survey question, i.e. "As you may have heard," "expanding the space program," and "Considering all the potential costs and benefits" affected the survey results far more than the deliberately-political nature of the question.

Take-Home Point: Be even warier of biased survey questions if uncorrected rumors are floating around.

Use of the term "cost" is another common bias whenever news reporters discuss space research. A more appropriate term is "investment," which implies that the outlays will be recovered over time, plus interest.

The primary route for space investment recovery is tax-revenue growth coupled to increases in

GDP (Gross Domestic Product). While highly subjective, various economic studies of the Apollo program have estimated the tangible ROI (return-on-investment) between 200% and 10,000%, depending upon the strictness of criteria used to evaluate the short-term and long-term benefits. Intangible ROI is even more difficult to assess but is unquestionably substantial.

While the numbers can be debated ad-infinitum, the simple fact that several professional economists have attempted to assess the ROI of the Apollo program is proof of the validity of the concept. The ROI of a pure "cost" is meaningless.

Take-Home Point: Use the term "investment" rather than "cost" when discussing space research and exploration funding.

Three later questions in the AP survey exploited other common misperceptions and biases. Question 2 directly implied the inherently-unproven premise that robotic exploration is more affordable than human exploration. Question 3 appealed to fear by stating bluntly that seven astronauts had been killed in a space shuttle accident. Worst of all, question 4 implied a spending-level equity between space research and "domestic programs such as health care and education."

BASELINE MISSION INVESTMENT

Establishing a proper context for manned space exploration investments is difficult without baselining a mission first. Without some reasonable understanding of the mission goals, timeframe, level of accepted risk, and investment-per-year, a space mission cannot be compared to other relevant governmental or private-industry programs.

However, a plethora of reasonable human spaceflight goals have been proposed by various organizations and individuals. Each requires a vastly different mission architecture, with different levels of up-front or ongoing investment. Even when the choices are limited to Mars exploration missions, at least a dozen mission profiles are currently being studied by NASA (the National Aeronautics and Space Administration) or various non-profit organizations.

For purposes of simplicity, we will use a well-studied Mars exploration mission proposal as a baseline mission in this paper: the Mars Direct plan, proposed by Robert Zubrin and David Baker in 1989.⁶ The required level of investment for the Mars Direct plan was reanalyzed by a joint NASA/ESA (European Space Agency) task force in 2003.⁷

The Mars Direct plan is science-driven. A crew of two scientists and two engineers will reside on Mars for a period of two years before returning to the Earth. Specialized mission hardware extends the safety, flexibility, and capability of the science team. Steps are taken to minimize all known risks, so the overall risk profile of the mission is modest when compared to other potential benchmark missions. Approximately 10 years would be required to develop, integrate, and test the hardware and software (including one mission), with an average yearly investment between \$2.7 billion (ESA) and \$3.9 billion (NASA). The on-going investment level to support 20 years of exploration missions, with one new mission every two Earth years, is estimated between \$2.6 billion (ESA) and \$3.5 billion (NASA). All estimates are in 2002-dollars.

On-going investment is the most-useful metric for this study. Few people remember the level of

investment necessary to create the first Space Shuttle (or even the name of the first Space Shuttle), yet the on-going budget allocation for the Space Shuttle program is clearly stated within the NASA budget every year.

Take-Home Point: "Ongoing investment-per-year" is the best metric to use.

Take-Home Point: A robust, science-driven Mars exploration program would require a yearly investment of approximately \$3.5 billion.

CONTEXT – NASA BUDGET

A Mars mission with human explorers may be funded privately or publicly. If public funding is used, the most likely source would be the NASA budget. To establish the investment context, we must examine the other investments in the yearly NASA budget.

The proposed 2005 budget for NASA is \$16.2 billion.⁸ Approximately half of the investment is closely related to human spaceflight. Major line-items are listed in Figure 2.

The VSE contains a specific recommendation to eliminate the Space Shuttle program after the International Space Station (ISS) has been built, around the year 2010. Barring any major shifts within the budget of NASA prior to 2010, the shuttle retirement would free a pool of \$4.3 billion per year. This amount is assumed to be more than adequate for funding an ongoing program of Mars exploration, baselined in the previous section at \$3.5 billion, without any budget increases, reallocation of the \$1.9 billion Exploration Systems budget, or impact on ISS support. In reality, these and other areas of the NASA budget would overlap with the manned Mars exploration program, reducing its cost, while the "Moon" portion of the VSE would add to the overall cost.

The VSE roadmap is ambiguous, and any congressional funding increases for NASA are highly speculative. Since a robust Mars exploration program can – and should - be supported within the proposed 2005 NASA human spaceflight budget (without redirecting any funds from elsewhere within NASA), the rest of this document will assume the levels of investment within the following Take-Home Points:

Take-Home Point: The proposed 2005 NASA budget is \$16.2 billion.

Take-Home Point: The proposed 2005 Human Spaceflight budget (including ISS) is \$8.6 billion.

Take-Home Point (repeated): A robust, science-driven Mars exploration program would require a yearly investment of approximately \$3.5 billion.

Unfortunately, \$16.2 billion per year, \$8.6 billion per year, and \$3.5 billion per year are still just abstract numbers to the American public. These levels of investment lack a proper context in relation to other expenditures more familiar to an average American.

CONTEXT – U.S. FEDERAL GOVERNMENT BUDGET

NASA's budget is allocated within the United States Federal Budget. Therefore, to establish a

proper context for investments into a publicly-funded Mars mission, human spaceflight, or space exploration in general, we must compare the NASA budget to other line-items within the United States Federal Budget.

The proposed United States Federal Budget for 2005 is \$2,400 billion, or \$2.4 *trillion*.⁹ The budget is complex, and the clarity of its presentation by the Office of Management and Budget (OMB) leaves a lot to be desired. However, browsing various OMB tables and sub-tables reveals numerous items of interest to most American taxpayers, items which can be used to establish a better context for space exploration investments (Figure 3).

Take-Home Point: The proposed 2005 NASA budget is less than 1% of the US Federal Budget.

The New Jersey retiree quoted by the AP survey was concerned about several line-items in the Federal Budget. Health care, welfare, and retirement security in the United States cumulatively cost well over a trillion taxpayer dollars each year. These important line-items can all be considered *costs*, rather than investments, because they generate no *direct* returns. The final *products* do not directly promote the creation of future products or directly guarantee additional government revenue. The programs preserve the health and financial opportunities of the current generation of taxpayers, retirees, and welfare recipients, or in some cases, their immediate descendants.

Theoretically, if the entire NASA budget was completely eliminated, \$16 billion could be reinvested into other government programs like the ones mentioned above. Due to the overwhelming percentage of Federal Budget dollars invested into these short-term programs, however, any reallocations would be practically unnoticeable.

Take-Home Point: Reallocating all \$16 billion of the NASA budget into the \$510 billion Social Security budget wouldn't even cover the annual adjustment for inflation. Eliminating the human spaceflight budget would be even less noticeable.

In fact, the cost of fraud within various short-term programs far exceeds the total level of investment into human spaceflight. Medicare and Medicaid fraud cost American taxpayers over \$25 billion each year, three times the investment into human spaceflight.

Furthermore, the cold reality of the current US Federal Budget situation renders these theoretical reallocation games totally meaningless. The US Federal Budget is not balanced, nor is it required to be. The *budget deficit* is a major, perpetual component of the United States Federal Budget (Figure 5).

The US Federal Budget Deficit acts as a buffer, ensuring that each line item in the budget stands or falls on its own merits. For example, the only real-world effect of completely eliminating the \$16 billion/year NASA budget would be to lower the budget deficit to \$429 billion, a mere 3.6% decrease. Short-term government programs like health care, welfare, and retirement security can't inherit a single dollar of the NASA budget without driving the adjusted-deficit higher... which Congress could do anyway, independent of any decisions about the NASA budget.

But what exactly *is* the US Federal Budget Deficit? Quite simply, it is the difference between

government revenues and expenditures. The US government currently borrows money to pay its expenses. Future generations of American taxpayers must repay this loan (plus interest) during years of budget surpluses. In other words, the US Federal Budget Deficit is an investment into the future of the United States – just as the NASA budget, the Department of Education budget, energy or technology research, and other forward-looking line-items are investments that expand the capabilities and resources of future Americans.

Long-term investments into NASA and the Department of Education are, by definition, completely compatible with the concept of deficit spending. Allocations that increase the US Federal Budget Deficit are justified if the rate of tangible and intangible return exceeds the amount of interest paid on the borrowed amount.

Take-Home Question: Since future generations will benefit from the space program, shouldn't future generations also pay for part of it?

An interest-only home mortgage is a common example of this principle in action. A consumer borrows a large amount of cash to buy a home and pays monthly interest on the amount borrowed. As long as the tangible and intangible benefits of owning the home exceed the interest paid, the new homeowner has made a good investment, even though her descendants might pay interest on the loan ad-infinity.

In theory, any department within the US government can take advantage of deficit spending if the rate-of-return justifies the expense. Deficit spending is most difficult to justify for short-term programs like Medicare and Medicaid. By contrast, the Apollo program has proven that the wealth of long-term tangible and intangible returns from the manned space program readily justifies deficit investment, even when pessimistic rates of return are assumed.

Since the United States government currently does not fund a program of manned Mars exploration, our context analysis would be incomplete without mentioning various programs that *are* funded. Digging into the OMB tables reveals hundreds of context-laden government-funded programs. Some examples are listed in Figure 5.

Our context analysis must also consider that the majority of funding for health, education, and welfare in the United States is by state, county, and local governments. However, the budgets of all fifty states vary widely and are difficult to obtain. An in-depth study must be left to greater economic experts.

Using the 2005 state budget for Colorado (an arbitrary choice), we can easily extrapolate the approximate spending levels of all state budgets combined.¹⁰ According to US census bureau estimates, the population of Colorado in July, 2005 will be ~4,400,000, which is 1.5% of the estimated 294,000,000 American citizens in August, 2004.¹¹

If a fair portion of Mars Direct was funded by the state of Colorado (Figure 6), the investment would be about \$50 million dollars, one-tenth the outlays of the Colorado Department of Human Services.

CONTEXT – U.S. ECONOMIC ACTIVITY

As massive as the United States federal and state budgets might be, the allocation levels are merely an anemic reflection of the United States Gross Domestic Product (GDP).¹² As the GDP grows, the Federal Budget grows. Over the past thirty years, the Federal Budget's percentage of the GDP has always remained near 20% (Figure 7).

The close linkage between the US GDP and the Federal Budget allows us to expand our context of manned Mars exploration investments into a realm that is even more familiar to every American citizen. While most people don't know where the US government spends its money, they know where *they* spend *their* money. Statistics for "household name" corporations and products are extremely useful for comparison purposes (Figure 8).

Take-Home Point: Mars Direct could be funded if one out of every eight ice cream purchases was donated to the public space program.

Take-Home Point: Mars Direct could be funded if one out of every twenty-five alcohol purchases was donated to the public space program.

Take-Home Point: Mars Direct could be funded if the impact of spam e-mail was reduced by 5%.

Take-Home Point: More money is invested every year into new golf course construction than into manned spaceflight.

Facts and figures, like the ones above, permeate every aspect of the American economy. American consumers spend far more each year on any number of household luxuries (cosmetics, travel, junk food, video games, sports tickets, etc) than their government invests into the space program.

The estimate of required investment for Mars Direct assumes no new technological innovations or improvements in economies-of-scale. The required investment for a privately-run Mars mission using business-world paradigms has never been reliably estimated, but it would undoubtedly be much cheaper than the public-mission estimates. Some back-of-the-envelope calculations lead the author to believe that under optimal circumstances, a privately-sponsored, manned Mars exploration program could be conducted for less than one billion dollars per year.¹³

CONCLUSION – AMERICAN PUBLIC PERCEPTION, REVISITED

The perceived weakness in public support for human space exploration is largely due to the following factors:

1. Cost vs. Investment mindset.
2. Lack of proper investment context.
3. Biased survey questions

What happens when these errors are corrected? Two recent surveys have attempted to answer this question by polling the public far more objectively than in previous surveys.

In July, 2004, the Gallup organization was asked to conduct a space exploration survey by the Coalition for Space Exploration.¹ The seven questions in the survey were intentionally formulated to avoid bias and to provide true, relevant background information. For example, a question about space exploration funding mentioned that currently, less than one percent of the federal budget was invested in space exploration.

The Gallup survey found that 66% of the American public agrees it is "important" for the United States to conduct both manned and unmanned space exploration (13% disagree). 68% support (and 24% oppose) the new VSE if the total investment was capped at 1% of the federal budget. The detailed results for each question reveal strong, broadly-based public support for manned space exploration across nearly all demographic groups.

An October, 2004 marketing-oriented survey by Dittmar Associates confirms the same level of support for the VSE (69%, with 26% opposed) and similar support for NASA funding increases of up to 1% of the Federal Budget for implementing the VSE.² The methodology of this study was more interview-oriented. Despite a potentially negative bias in the results caused by a political reference in an early question, faulty economic assumptions were corrected and the overall results of the survey seem credible.

The American taxpayers appear to be too generous, if anything. 1% of the proposed 2005 United States Federal Budget is \$24 billion dollars, an amount dwarfing the \$3.5 billion per-year ongoing cost estimate for Mars Direct. NASA could conduct seven robust Mars exploration programs with the funds that most taxpayers are willing to invest.

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TABLES AND FIGURES

Figure 1 (Results for Zogby Survey Question 2):

Less than 1%	(20%)
1% to 5%	(37%)
5% to 10%	(19%)
More than 10%	(17%)
Not Sure	(8%)

Figure 2 (2005 Proposed NASA Budget):

2005 NASA OUTLAYS (proposed)	2005-Dollars (billions)	NASA Budget %
TOTAL NASA BUDGET	\$ 16.2	100.0
Space Science	\$ 4.1	25.3
Earth Science	\$ 1.5	9.3
Biological/Physical Research	\$ 1.0	6.2
Aeronautics	\$ 0.9	5.6
Education	\$ 0.2	1.2
Space Station, Operations	\$ 2.4	14.8
Space Shuttle	\$ 4.3	26.5
Exploration Systems	\$ 1.9	11.7

Figure 3 (2005 Proposed U.S. Budget):

<i>2005 US OUTLAYS (proposed)</i>	<i>2005-Dollars (billions)</i>	<i>US Budget %</i>
TOTAL US BUDGET	\$ 2400	100.0
Social Security	\$ 510	21.3
Medicare/Medicaid	\$ 478	19.9
Defense	\$ 429	17.9
Health & Human Services	\$ 68	2.8
Education	\$ 57	2.4
Homeland Security	\$ 47	2.0
Housing and Urban Development	\$ 31	1.3
NASA	\$ 16	0.7
[NASA Human Spaceflight]	[\$ 8.6]	[0.4]
[Mars Direct (ongoing)]	[\$ 3.5]	[0.1]

Figure 4 (2005 Proposed U.S. Budget with Deficit):

<i>2005 US OUTLAYS (proposed)</i>	<i>2005-Dollars (billions)</i>	<i>US Budget %</i>
TOTAL US BUDGET	\$ 2400	100.0
Social Security	\$ 510	21.3
Medicare/Medicaid	\$ 478	19.9
Budget Deficit (anticipated, 07/2004)	\$ 445	18.5
Defense	\$ 429	17.9
Health & Human Services	\$ 68	2.8
Education	\$ 57	2.4
Homeland Security	\$ 47	2.0
Housing and Urban Development	\$ 31	1.3
NASA	\$ 16	0.7
[NASA Human Spaceflight]	[\$ 8.6]	[0.4]
[Mars Direct (ongoing)]	[\$ 3.5]	[0.1]

Figure 5 (Miscellaneous U.S. Government Outlays):

<i>MISCELLANEOUS US OUTLAYS</i>	<i>Dollars (billions)</i>
TOTAL US BUDGET (2005)	\$ 2400
Iraq war (estimated, cost in 2003)	\$ 75
Proposed highway improvement bill (2004)	\$ 53
Airline bailout (2002)	\$ 20
Farm subsidies (2004)	\$ 19
Missile defense system (2004)	\$ 9
[Mars Direct (ongoing)]	[\$ 3.5]

Figure 6 (2005 Colorado and Cumulative State Budgets – Estimated):

<i>2005 STATE PROGRAMS</i>	<i>Colorado Cost (billions)</i>	<i>Extrapolated US Cost (billions)</i>
TOTAL COLORADO BUDGET	\$ 5.6	\$ 374
Department of Education	\$ 3.2	\$ 214
Department of Health Care	\$ 1.2	\$ 83
Department of Human Services	\$ 0.5	\$ 31
[Mars Direct (ongoing, reverse extrapolation)]	[\$ 0.05]	[\$ 3.5]

Figure 7 (U.S. Gross Domestic Product):

<i>ECONOMIC COMPONENT</i>	<i>2005-Dollars (billions)</i>	<i>GDP %</i>
TOTAL US GDP (8/2003-7/2004)	\$ 11649	100.00
US Budget (proposed, 2005)	\$ 2400	20.60
[Mars Direct (ongoing)]	[\$ 3.5]	[0.03]

Figure 8 (Miscellaneous GDP Statistics):

<i>MISCELLANEOUS GDP COMPONENTS</i>	<i>Dollars (billions)</i>
Microsoft Corp. revenue (2004)	\$ 37
Microsoft Corp cash reserve (mid-2004)	\$ 50
Microsoft Corp special dividend to shareholders (2004)	\$ 32
General Motors revenue (2003)	\$ 186
General Motors assets (end-2003)	\$ 288
Walmart revenue (2 nd quarter, 2004)	\$ 70
State Farm insurance "administrative fees" (2003)	\$ 7
US golf course construction investments (1990's)	\$ 95
Assets of 10 random investment management firms (2003)	\$ 3907
Europe/US ice cream purchases (yearly)	\$ 31
US alcoholic beverage sales (2002)	\$ 114
Worldwide artwork sales (yearly)	\$ 100
US cost of spam e-mail (estimated, yearly)	\$ 87
[Mars Direct (ongoing)]	[\$ 3.5]