The space race of the 1960s attracted a concentrated peak in space funding which has not since been repeated. Based on a novel methodology of new Internet–sourced, computer–driven visual text analytic techniques, this study suggests that the advances in engineering technologies supported by this funding — especially robotic, unmanned missions to space involving international cooperation such as the 2012 Curiosity landing on Mars — have resulted in decreased public interest, engagement, understanding of and ultimately support for space exploration and ultimately human–carrying spacecraft development. We suggest consequences for public interaction with, and political and economic support for future spacecraft development.

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## Introduction

At least two metrics — aside from broad–acre polling and meticulous focus groups — are available for assessing how the space race has affected, and can affect, public communicative interaction with space exploration and thus spacecraft development. The first captures a long–range picture and looks at the rate and distribution of funding in national budgets for space exploration activities; the second is more immediate and involves social media monitoring on the Internet.

Use of the first suggests that NASA funding for space exploration peaked dramatically during the 1960s space race and has then gradually dwindled (Kring, 2010a). Further, even as direct NASA funding has lessened, wider funding in the European Space Agency and from the BRIC nations (Brazil, Russia, India and China) has increased (OECD, 2011) although not to the extent of the 1960s. Direct expenditure on space exploration has also increased from non–government sources and the trajectory is upwards (Cokley, *et al.*, 2013). This metric relies on the assumption that public spending is based on more than scientific or commercial policy but draws much of its strength from electoral support among general citizens: if spending is high it's because politicians assess public support as high, not the other way round. This suggests a positive link between the public's understanding of the space race as “important” and the budget allocations made for space exploration.

Use of the second method suggests that public interest remains high at least when major announcements about space exploration are made even 35 years after the first lunar landing. The latest instance of this occurred early in May 2012 when the European Space Agency (ESA) announced plans for a new €1 billion mission to search for extra–terrestrial life in outer space, this time to three of Jupiter's largest moons: Ganymede, Callisto, and Europa (Handwerk, 2012). Four days after that report was published on the National Geographic Web site [1], it had attracted 11 comments, 32 Google+ “Shares”, 104 Tweets and more than 8,200 FaceBook “Like” shares. This single but apposite case is an example of “Scientometrics 2.0” (Priem and Hemminger, 2010) in which social media traffic is used to evaluate and filter articles for general appeal, relevance and impact. Higher traffic can be interpreted as suggesting higher public understanding (although the method is much more complex than this simple statement implies) and this...
also suggests a positive link between the public’s understanding of the space race as "important" and individuals’ willingness to engage in social media activity.

At a deeper level, both the preceding examples suggest that politicians, scientists and news publishers jointly believe that the space race has been and continues to be a positive driver for general society’s understanding of, and engagement with, space exploration and even science more generally. Evidence exists to support this suggestion in two places. The first is another economic picture, which suggests that as U.S. government allocations to NASA decreased after the Apollo missions to the Moon, allocations to the U.S. National Institutes for Health (NIH) took off and increased at a similar rate to that at which NASA allocations fell (Kring, 2010b). NASA allocations fell from US$20 billion in 1969 to just under US$15 billion in 1999 and have remained there ever since, while NIH allocations rose steadily from US$5 billion in 1969 to slightly more than US$15 billion in 1999 but kept on increasing to US$25 billion in 2003, where they have plateaued. In general, the two science–based funding streams have run parallel since 2003.

The second indicator that the space race is a driver of public opinion is the key statement for the U.S.–based Universities Space Research Association (USRA) established in 1969 at the peak of the space race and “driven by the vision of two individuals, James Webb (NASA Administrator 1961–1968) and Frederick Seitz (National Academy of Sciences President 1962–1969)” (USRA, 2012):

Together, they worked to create USRA to satisfy not only the ongoing need for innovation in space, but also the need to involve society more broadly so the benefits of space activities would be realized.

Almost in their own words, the top U.S. space race official and the top Academy of Sciences official of their day drew a straight line between the space race and the public “involvement” in (which suggests “understanding of” or “engagement with”) space science. Hence, we ask: What have been the characteristics of that understanding? What have the public — and by extension policy–makers, politicians and funding allocators — been understanding in the term “space race”? What’s been going on here? For an answer, we turned to the research literature which has been informing scientists, policy–makers, journalists and ultimately their audiences in the half–century of the space race.

There are important implications in this research for space nations outside the U.S. The European Union, India, China, Russia and even Australia all have space assets and either well–established or developing space policies. These groups or nation states would benefit from research which clearly identifies policy drivers and inhibitors in the space sector.

Methodology

A purposive sample was taken in January 2012 of scholarly articles published between 1937 and the 2012 and now indexed by what is arguably the largest and most diverse database of scholarly articles to date, Google Scholar on the World Wide Web. The search was conducted once, using the terms “public opinion” and “space exploration” together as shown, resulting in 2,590 items being listed. Jacsó [2] notes that this search engine includes access to:

... the huge databases of the largest and most well–known scholarly publishers and university presses (such as IEEE, ACM, Macmillan, Wiley, University of Chicago [... with the notable exception at the time of Elsevier, the largest publisher ...] [3]);
their digital hosts/facilitators (such as HighWire Press, MetaPress, Ingenta); societies and other scholarly organizations and government agencies (such as the American Physical Society, National Institute of Health, NOAA), and preprint/reprint servers (such as arXiv.org, Astrophysics Data System, RePEc, and CiteBase).

Jacsó [4] notes that the search engine at that time limited the indexing of each file to the first 100–200KB of the text, even though many articles were around 1MB, and that this would limit the number of returns in each search. This limitation was later echoed by Falagas, et al. [5] who report that “Google Scholar ... can help in the retrieval of even the most obscure information but its use is marred by inadequate, less–often updated citation information”. However, an advantage of Google Scholar is that the search results groups all duplicates, reducing the time and effort required to trawl through articles which might be published or stored in different locations. Thus when the search for this article was undertaken and the 2,590 items were displayed, only unique listings showed and duplicates were not counted.

A varying degree of relevance to the topic was observed among the search results. First–stage analysis
involved co–author Cokley browsing manually through the grouped search results and downloading articles. Articles about public opinion, media analysis and public understanding of science were included as well as articles about space exploration, spacecraft and the space race. Before commencing a research career in 2002, Cokley worked as a science and technology journalist from 1984 and this experience helped him to establish that relevance of results decreased below a useful level after about 400 unique entries. At that stage 70 articles had been retrieved from a range of popular, scientific and academic databases. These articles became the corpus of our data.

Second–stage analysis was conducted using a novel combination of new computer–based visual text analytic techniques. Visual text analytic techniques are hybrid machine learning and information visualisation techniques that look for patterns in text data and generate informative visual representations of relationships found. These techniques are useful for exploratory data analysis where relationships between key phrases are unknown, or where a relationship is assumed and the technique can inform on the validity of such an assumption. Leximancer™ (Smith, 2003; Smith and Humphreys, 2006) is a commercially available visual text analytic system that represents the prominent concepts from an input text corpus on a two–dimensional map, with theme circles grouping coherent sections of the map into clusters and a spanning tree connecting related concepts. Leximancer focuses on spatial aspects of input text (how concepts extracted from the text are related to each other) and has been used to analyse opinion polling and political commentary (McKenna and Waddell, 2007); to evaluate incident reporting in a maritime environment (Grech, et al., 2002); and to explore communication strategies employed by care providers of persons with schizophrenia (Cretchley, et al., 2010). Leximancer uses word occurrence and co–occurrence statistics to determine the relatedness of key terms with the most prominent key terms becoming concepts. Leximancer has the capacity to model not only the spatial relationships between key concepts, but to also the sentiment relationships within input text. Sentiment can be modelled by using known lists of positive and negative sentiment terms and looking for supporting evidence of these terms being used in conjunction with key concepts. For example, the terms “bad, poor, lazy, evil” are evidence for concepts in their immediate vicinity having a negative sentiment.

Leximancer was used to analyse the full text of the 70 articles published between 1937 and 2012. Of interest in this study was the relationship of key concepts to nation states and scientific organisations, in addition to the sentiment of key concepts.

Results
Overall sentiment

Sentiment tracks the use of concepts in relation to a list of known positive and negative sentiment terms. From the 70 articles it is apparent that issues such as high economic cost, long time spans involved in development of space exploration, and politicising of space endeavours are seen as strong detractors from such endeavours. In contrast to this, social benefits such as technological advancement and the use of space to project power in a geopolitical sense are seen as positives.

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>American</td>
<td>problems</td>
</tr>
<tr>
<td>Efforts</td>
<td>cost</td>
</tr>
<tr>
<td>Cost</td>
<td>technologies</td>
</tr>
<tr>
<td>Social</td>
<td>community</td>
</tr>
<tr>
<td>Attitudes</td>
<td>process</td>
</tr>
<tr>
<td>Work</td>
<td>least</td>
</tr>
<tr>
<td>Planetary</td>
<td>nuclear</td>
</tr>
<tr>
<td>Problems</td>
<td>technological</td>
</tr>
<tr>
<td>Support</td>
<td>recent</td>
</tr>
</tbody>
</table>
**Major thematic content**

The Leximancer map in Figure 1 shows all 70 articles plotted together. Seven thematic groups were identified: Human, International, Media, NASA, Proposed, Public Opinion and Space. The literature was then manually subdivided into these seven themes and individual maps were generated for each group. This thematic breakdown affords a better insight into the concepts and their interrelationship per theme group. Each theme is discussed in turn below.

For each theme group the top concepts that are related to the concept "space" were extracted:

<table>
<thead>
<tr>
<th>Concept Rank</th>
<th>Human</th>
<th>International</th>
<th>Media</th>
<th>NASA</th>
<th>Proposed</th>
<th>Public Opinion</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Exploration</td>
<td>China</td>
<td>Media</td>
<td>NASA</td>
<td>Exploration</td>
<td>Public Exploration</td>
<td>Exploration</td>
</tr>
<tr>
<td>2</td>
<td>Important</td>
<td>Mechanism</td>
<td>News</td>
<td>Public</td>
<td>Mars</td>
<td>Exploration</td>
<td>Human</td>
</tr>
<tr>
<td>3</td>
<td>Experience</td>
<td>Cooperation</td>
<td>Mass</td>
<td>Budget</td>
<td>Human</td>
<td>Science</td>
<td>NASA</td>
</tr>
<tr>
<td>4</td>
<td>Commitment</td>
<td>Policy</td>
<td>Coverage</td>
<td>Policy</td>
<td>missions</td>
<td>support</td>
<td>Program</td>
</tr>
<tr>
<td>5</td>
<td>Human</td>
<td>Exploration</td>
<td>Public</td>
<td>opinion</td>
<td>moon</td>
<td>opinion</td>
<td>Mars</td>
</tr>
</tbody>
</table>

**Human**

This theme tends to contain concepts surrounding lunar exploration, specifically the moon landing. The articles included here tend be mostly about the human relationship with, and experience of, space especially aspects such as human (manned) exploration, commitment to future exploration and discovery, and important missions. It also contains discussion around champions of space including scientists and documentary filmmakers such as Carl Sagan.

**Robots versus humans**

The concepts 'human' and 'robotic' are linked through the concept 'missions'. The use of 'human' in this context refers to manned space missions. 'Robotic' has a three times higher likelihood of inferring the concept 'missions' than 'human' does. When 'missions' is used it is more likely to be in the context of robotic missions such as the Mars Lander, than in the context of manned missions such as the space shuttle program or the International Space Station (ISS).
**Figure 2:** Leximancer map of the ‘human’ theme group. This theme incorporates concepts of lunar space exploration.

**International**

This theme covers the international policy issues related to space. Aspects of global cooperation are prominent with major international space agencies including NASA and the ESA mentioned, in addition to specific countries: U.S., Russia, China. Some discussion of satellites is also interesting as this is certainly one area of significant international interest.
Figure 3: Leximancer map of the 'international' theme group. This theme incorporates concepts representing policy issues that surround global space cooperation.

Media

The media theme contains thematic content which covers modes of media delivery including television and newspapers. More importantly it shows how the public is central to the discussion of media in relation to space. Concepts such as Soviet and American are present which are no doubt related to the space race, an event which has been highly reported in the media. Leximancer connects the concept of “public” to “affairs”, “opinion”, “knowledge”, “science” and “information” in that order. This is interesting given that affairs and opinion are given a higher relevance than are knowledge, science or information, suggesting that the facts take a back seat to opinion in the reporting of space science.
Figure 4: Leximancer map of the 'media' theme group. Concepts included in this map highlight the role of the press in communicating space exploration, specifically the important role of lunar space missions.

NASA

In this map there is an abundance of talk around budgets, policy, spending, funding and opinion. It appears that the issues of research, science, technology and the programme take a back seat to concerns about how much is being spent at NASA.
Proposed

As the name suggests, articles here mostly talk about future space exploration and proposed missions. Mars is a large theme within this context and it appears that in many ways Mars is Moon 2.0 for the current generation. Linked with Mars is the concept of life, and this relates to the search for life outside Earth. "International" is a theme within the map, in addition to ISS (International Space Station), and it appears that there is some focus on international cooperation when any future space program is discussed. Absence of significant mention of Jupiter is surprising and interesting, given the 2012 ESA announcement of the JUICE project. Mention of Jupiter might have been expected in the lead-up to this announcement.

Public opinion

This theme emerged as a control theme in the investigation. In these articles, concepts such as "surveys" and "sample groups" are shown strongly linked and these are evidence of techniques used over the years to obtain ideas around public opinion of space exploration and research. Issues discussed in the articles
include technology, innovation, education, activities, understanding, economic and scientific. The fact that “public” and “opinion” occupy strong clusters in the centre of the map strongly supports the finding that the articles selected really do centre on these issues.

**Figure 7:** Leximancer map of the ‘public opinion’ theme group. This theme group includes many concepts that relate to the methods by which other studies have tried to measure public opinion, and concepts which shape public opinion.

*Space*

This is an interesting group as in many ways the entire corpus of articles is about space, and space is the biggest concept for the entire dataset. However “space” in the context of these articles is around “space exploration” and how such activity is affected through technology (launch), policy, and programs (“What are we doing? Let’s go to Mars!”).
Figure 8: Leximancer map of the ‘space’ theme group. The space theme could be renamed ‘space exploration’ as the concepts revealed mostly relate to exploration (past, present and future). The high salience of the concept cluster ‘Mars’ highlights the importance of Mars in space exploration activities.

Discussion and conclusions

The visual text analytic techniques most strongly suggest that the use of unmanned robotic space missions has resulted in a decrease in the public’s awareness of space travel and exploration as an endeavour directly involving humans: in effect, from being a race between humans, to being a race by robots controlled by humans. A succinct example of this is a comparison between the intense drama of the 1970 manned Apollo 13 lunar mission, in which U.S. astronauts seemed to be trapped in space, and the 2004 Mars landing of the robotic explorers, anthropomorphised with the names Spirit and Opportunity. Public fascination and elation at the recovery of the 1970 astronauts was widely acknowledged and then revived in the movie of 1995, but 24 years later NASA never made any attempt to recover Spirit and Opportunity. The little robots were left there, far away out in space ... and they’re still there [6].

This broad finding, when coupled with the findings that the space race is associated with high economic cost, long time lines in development and politicisation, helps explain the observed reduction in budgetary allocations to NASA since 1969 (Kring, 2010a) despite the recognition of technological advancement and the use of space, especially the ISS, to project geopolitical power. One explanation is that the USRA strategy — emphasising “the need to involve society more broadly” in space exploration (USRA, 2012) — was correct but has failed because of engineering advances. By developing and funding robotic missions into space — possibly driven by deaths in the Apollo and Space Shuttle programs — scientists and politicians have unwittingly diluted public interest, engagement, support and perhaps even public
understanding of space science. The NIH has been able to redirect public understanding of technological advances and reap the budgetary rewards (Kring, 2010b).

Additional factors in the dilution of public engagement are evident in the visual text analysis of “international”. While this suggests an awareness of increased global cooperation it simultaneously reduces the drama, tension and urgency evident in a race between specific countries who adopt the stance of rivals. Analysis of “media” suggests that “opinion” has taken precedence over “knowledge”, “science” and “information”, leading to a lack of public trust in the space project, or at least in the way the space project is being communicated. This is supported by analysis of “NASA” as an institution of research but which spends too much ... even though budget allocations were drastically cut after the Apollo missions and have remained flat ever since. With such public understanding evident, politicians could feel prompted to keep cutting NASA allocations. Looking forward, analysis of “proposed” missions which views future exploration as international–or–nothing suggests a further dilution of space–race urgency and a concomitant reduction in public engagement and deep understanding.

Recommendations

Space

How should the space exploration and spacecraft development disciplines respond to such an analysis? Robotic missions to explore and possibly mine other planets are cheaper and safer than human missions ... but they will have to be because using them will drive down funding. Similarly, collaborative international missions are more the rule than the exception ... but these will be more necessary to spread the financial load between the participants. NASA should consider its media image as a big–spending researcher ... and try to refashion itself as an efficient researcher (which deserves appropriate support). The European Union, India, China, Russia and even Australia can learn from these experiences and formulate relevant and appropriate policies to suit.

Science in general

It has long been recognised that public understanding of and engagement with science is an important lever connected to political support and budgetary allocations. But this study has shown, in a novel way, some of the drivers of that lever. Engineering advances can remove much of the human element involved in scientific endeavours, such as experimentation, but the occasional human intervention stands out all the more for this.

Some might say ordinary people have become disenfranchised by the stunning array of technology in medical science which enables gene research and possibly a cure for cancer ... but it was the even more stunning self–experimentation by Australia’s Dr. Barry Marshall in 1984, by drinking a culture of bacterium *Helicobacter pylori* to demonstrate the cause of most peptic ulcers, that caught the public’s eye when he was awarded the Nobel Prize (with colleague Dr. Robin Warren) in 2005 [7]. Another illustration is the reduced public support for large–scale military actions such as in Iraq or Afghanistan, which uses remotely guided missiles and drone aircraft to carry out dangerous missions, compared with the public engagement with and support for individual soldiers awarded the Victoria Cross or the Congressional Medal of Honor for individual valour in the face of danger. Finally, the international collaboration required to fund and maintain substantial scientific or engineering endeavours such as climate research in the Antarctic can be lost in the media opinion about climate change, but the efforts of a single heroic researcher or polar explorer such as Douglas Mawson are unambiguously understood by the man and woman in the street.

For those designing spacecraft today and looking for a major boost of public interest and funding, this study suggests incorporation of some explicit reference to human spaceflight. In light of this, current experiments with space tourism and space hotels (Cokley, et al., 2013) could provide some support for spacecraft development.

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Notes


3. Italics added, and it is noted that Elsevier has since been indexed.


References


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