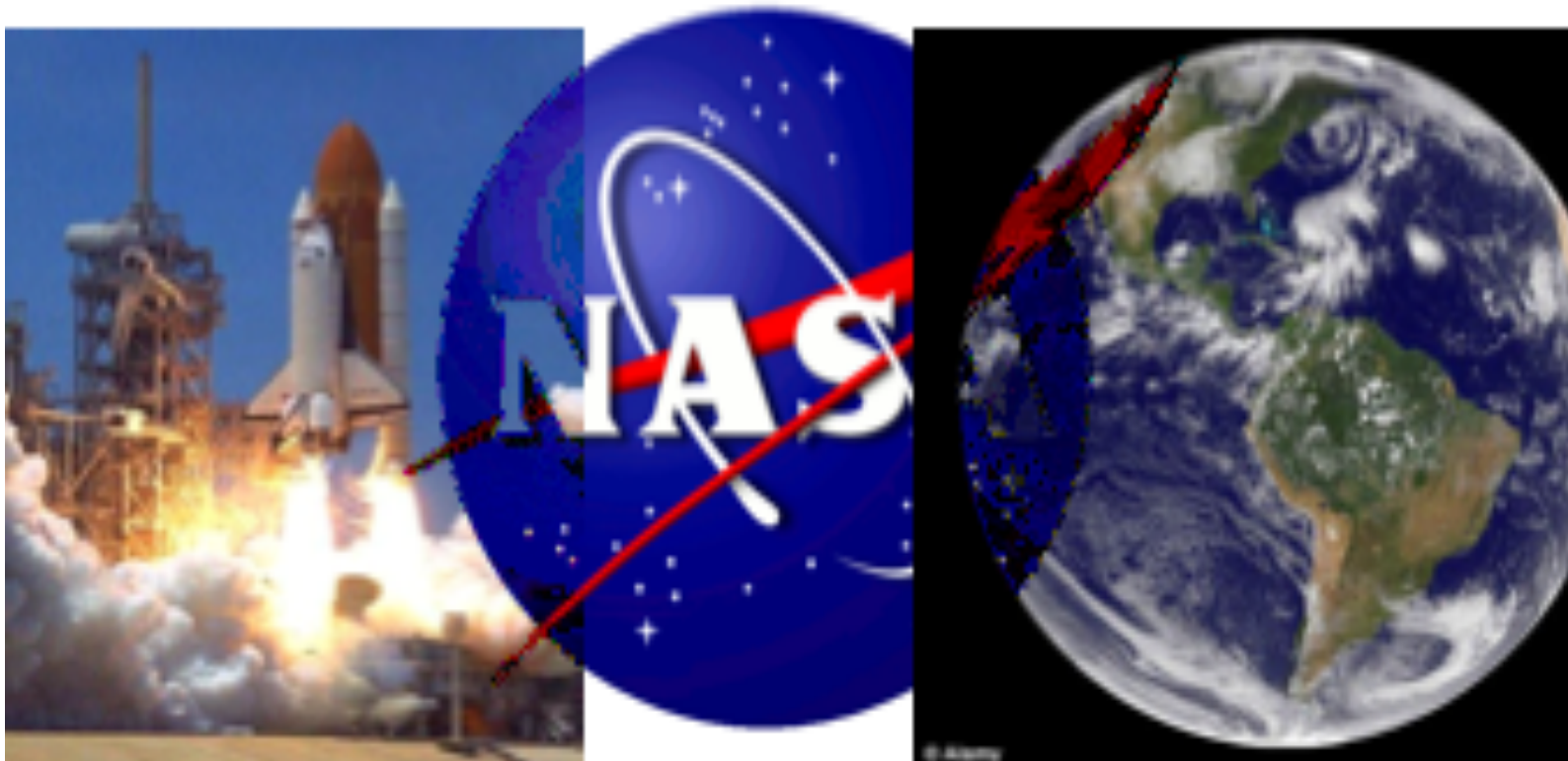


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Innovations from Space Having A Real Impact on Earth
A Benefits and Limitations Analysis Perspective



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Executive Summary

NASA's aerospace research has created feasible benefits back to Earth in the form of commercial products and services in the fields of medicine, environmental and energy resources, transportation, computer technology and consumer goods. The benefits have spread throughout the economy and around the globe. However, the research shows that although benefits are notable, the benefits could have been larger if NASA had undertaken a more holistic approach to managing its diverse programs and projects. The objective of this report is to analyse the role NASA plays in innovation, examine how space exploration impacts our daily life, and identify solutions on how NASA should change to make their innovations more valuable. This is accomplished through review of the many innovations which were developed for space exploration projects, and their effect on our life on Earth. The transfer of developed technologies for public benefit in various areas was analysed. Benefits and limitations were identified, lessons learned synthesized and proper recommendations made. The following are the key findings.

Institutional Role of NASA in Innovation

NASA as a US national institution is in a special role in its ability to influence innovation. As the organization tasked with the responsibility for advancing aerospace science, it is intimately involved with many of the technological developments necessary to further travel into space. In addition, it is able to affect how we travel in our own airspace on earth more effectively, in economic, technological, and environmental terms. The advancements of these technological innovations implies the US and the world will benefit advantageously in the realm of social, political, military, and economic domains as a result of its development in science, technology, engineering, and mathematical technical disciplines, through which NASA is assisting to improve in. To facilitate these technological advances, NASA runs several funding programs targeted to outside organizations for scientific advancements beyond NASA's core competencies, with an office established to manage technology development with small businesses. All improvements done under NASA's funding agreements must be reported to NASA, some of which may find its way into NASA's patent portfolio easily searchable and accessible online through its Technology Transfer Portal. NASA aims to encourage innovation, and enable it to further carry out its mission and vision as stated in its strategic plan of 2014.

Medicine and Healthcare

NASA's innovations in space exploration have greatly changed the medical industry as we know it. NASA research developed robotic and teleoperator technology which led to the voice controlled wheelchair, allowing quadriplegics freedom they never had before. NASA research at its Jet Propulsion Laboratory developed the cool laser, which opened the door to laser angioplasty, a procedure which clears human arteries of dangerous plaque in a less invasive ways than other methods. Finally, NASA research on the Hubble Telescope created the charged coupled device which led to increased clarity in breast imaging, ultimately leading to stereotactic breast biopsies, which allow doctors to test for breast cancer with increased efficiency and reduced cost.



Environment in Energy

NASA's programs have cultivated numerous inventions and partnerships were formed to transfer developed technologies for public benefit in the Environmental and Energy sector. In the environmental sector, the collaboration between NASA and Google resulted in the Google Earth Engine, a project designed to use the Landsat Earth observation database to facilitate global change monitoring. In the energy sector, the dividends are brought by the Redox flow battery technology initially developed during the Apollo project. NASA's partnership with Deeya Energy developed the initial Redox flow battery into a hybrid flow battery technology that delivers higher charge efficiency than standard rechargeable batteries. The research identifies that to a large extent NASA's research and development in this field is revolutionary, developing innovative technologies. However, the complex regulations, intellectual property challenges, inadequate funding, inconsistencies in the technology transfer programs and lack of collaboration with private sector often reduce the successful launching and implementation of technology into the commercial sector, resulting in less than optimal benefits. There is a shift change from the approach that operations have been managed a few years ago to the approach that they must be operated today. The challenges today pertain not only to the technology and its management, but also to human-centric factors such as communication, processes and planning, and cultural aspects as well. The question then arises as to whether the agency has the ability to operate in a new environment that requires ongoing change? Given the importance of innovation, NASA shall be oriented toward being an organization that promotes a tomorrow that is tuned to the future, an external environment that addresses the needs of all stakeholders and a culture of innovation that encourages individuals who initiate change.

Transportation

NASA's Space Shuttle program originally developed to transport astronauts and science experiment payloads to the International Space Station (ISS) has also brought about benefits to transportation on Earth. Collaborative efforts with The Boeing Company lead to the introduction of the Boeing 777 aircraft, a wide body twin-engine aircraft designed entirely using a computer. NASA's applied research facilities also contributed to the success of the Boeing 777, however Boeing reimbursed NASA for the use of these facilities, and therefore this contribution is treated more like a supplier than a partner. Greater technological advances in airplane design and travel can be accomplished if NASA is more open-minded to working with other space agencies. Space Act Agreements allowed NASCAR racers access to materials used to shield the Shuttle during its re-entry. These materials now shield the drivers from intense heat and make racing far less dangerous. However these agreements are difficult to enter into due to IP and US government legislature, in addition private sector companies require their own financial backing to enter into these agreements making it only available to the elite. Greater progress can be made if NASA takes the role of an agent and negotiator to develop partnerships between private sector companies and government agencies in order to help these companies overcome financing difficulties.



Computer Technologies

Throughout NASA's developments, the agency created numerous technologies for its internal use. One such technology is a power converter to be used in harsh environments; this technology is created in conjunction with a small company call VPT and can operate in the harsh environments of space. It has since been adapted for use in harsh environments on earth. However, one drawback is that VPT is a relatively small company and is the only collaborator with NASA regarding this technology. If VPT experiences any setback, then the means to manufacture the power converter is lost. In NASA's telescopes, advanced image processing software were developed to properly analysis the images of stars and earth. The software and the platform it operates on are hugely powerful and can cross reference data from different satellite and images to produce a detailed analysis of results. NASA has made the analysis platform public and allows anyone to adopt it for personal use. However, the barrier to entry is still very high as it requires individuals or companies to have the means to acquire raw unprocessed satellite images and therefore difficult to obtain. NASA also only provided the platform without the processing algorithm which needs highly specialized individuals to develop. It is therefore recommended to NASA that they collaborate with more companies on its technology development process to ensure that setbacks on one company will not affect the overall objective. The public would also benefit from NASA releasing more of its algorithms, software, and raw satellite data to reduce the barrier of entry.

Consumer Products

A consumer product has many attributes that make it suitable for a particular purpose. In the case of NASA, this has largely been accomplished via the NASA Innovative Partnerships program, which has helped transfer NASA technology to the private sector. One shining example would be the development of a water filtration system using acoustic nanotube technology, which provided a cheap and scalable method of filtering water in areas that couldn't afford it. The 360° FFL cameras used in the Mastcam system on Curiosity were jointly developed with Malin Space Systems, and gave birth to panoramic photography products such as the Bublcam and GIROPTIC. Although economical, issues related to biological accumulation, sizes and safe disposal still exist that impede the speedy adoption of the same. It is recommended that NASA work in concert with its partners and industry to overcome these challenges and thereby enable the public to appreciate the significant benefits of the research leading to the development of these products.

Concluding Remarks

The complicated and lengthy federal government procedures, lack of collaboration, some intellectual property difficulties, and various inconsistencies in the technology transfer programs often inhibit or delay the successful launching and implementation of technology, resulting in less than optimal benefits, and sometimes substantially delaying the transfer of new technologies into the private sector. Solving these issues facing the space agency require a more collaborative attitude that forms upon teamwork and knowledge of all stakeholders. Furthermore, it should be asserted that innovation gets achieved through lessons learned and through transformation.



Moving forward, NASA should:

- Be oriented toward being an organization that promotes a tomorrow that is tuned to the future demands, an external environment that addresses the needs of all stakeholders and a culture of innovation that encourages individuals who initiate change.
- Make effort toward developing programs and policies that inspire a degree of trust between businesses and government.
- Consider a more proactive collaboration with other space agencies as it is in everyone's interest to explore space, the agencies should find ways to work together and share rather than compete and work in secrecy.
- Act as an agent and negotiator to develop partnerships between private sector companies and government agencies in order to help these companies overcome financing difficulties.
- Work in concert with its partners and industry to overcome challenges and thereby enable the public to appreciate the significant benefits of the research leading to the development of novel products.
- Release more data, algorithm, and software to the public to reduce the barrier of entry into the field thereby receiving more collaboration with the public.
- Check the progress and the impact on the economy of transferred technologies continuously.
- Improve the knowledge management system by sharing knowledge, integrating distributed knowledge, capturing knowledge and modeling expert knowledge more efficiently.

Finally, it should be emphasized that these issues are challenges to both NASA management and personnel. Since innovation is accomplished through people in organizations, this report encourages NASA management and personnel to challenge these issues and make their innovations even more valuable to society.