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TRAINING CREATIVE ENGINEERS: THE ARCTURUS IV CASE STUDY AND ITS RELATION TO MDRS

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ABSTRACT

To survive and flourish, Marsnauts will need to deal with unpredictable challenges caused by the combination of the extreme environment, reliance on advanced technology, and remoteness from Earth's capabilities and resources. Marsnauts will need to be "creative engineers," a concept promoted by John E. Arnold, a psychologist and mechanical engineering professor at MIT and Stanford University in the 1950s. Believing engineers should address the most challenging problems of society, Arnold asked, "How can we raise the level of creative thinking? How can we train engineering students to use their imaginations, to speculate? The need for men of creative ability is as great or greater than at any time in our history yet it is becoming increasingly difficult to find them. An emphasis on security is strangling our pioneering spirit."

To promote what today we call "design thinking," Arnold presented a science fiction case study that asked students to design products for Methanians, beings who live on Arcturus IV in 2951. To promote realism, the case material for learning about the Methanians' physical, social-psychological, and environmental needs was presented as a file of official letters and reports organized by a government agency on Terra that regulated trade with other planets.

Arnold thus transformed "engineering design" from draftsmanship to an empirical problem-solving method. Inquiry about the Methanians provided an unbridled, stimulating atmosphere that encouraged speculation, unlike textbook engineering, and particularly conveyed that engineers must relate people and their environment: "…too many take our earthly conditions for granted…[without considering] the effects of temperature, atmosphere, gravity, etc. on the products they are designing."

For today's engineers, Mars is Arcturus IV, and designing for Marsnauts is designing for beings on another planet. In effect, crews role-playing at MDRS speculate and imagine what it will be like to be Marsnauts, as living participants in a case study of creative engineering.

INTRODUCTION

My presentation today is about a science fiction story, Arcturus IV, that was used in the early 1950s for teaching engineers to be creative.* It is a method for promoting innovation, combining role-playing and imagination, which we have brought to life at MDRS. Arcturus IV was conceived by MIT Professor John Arnold, for his Mechanical Engineering product design class.

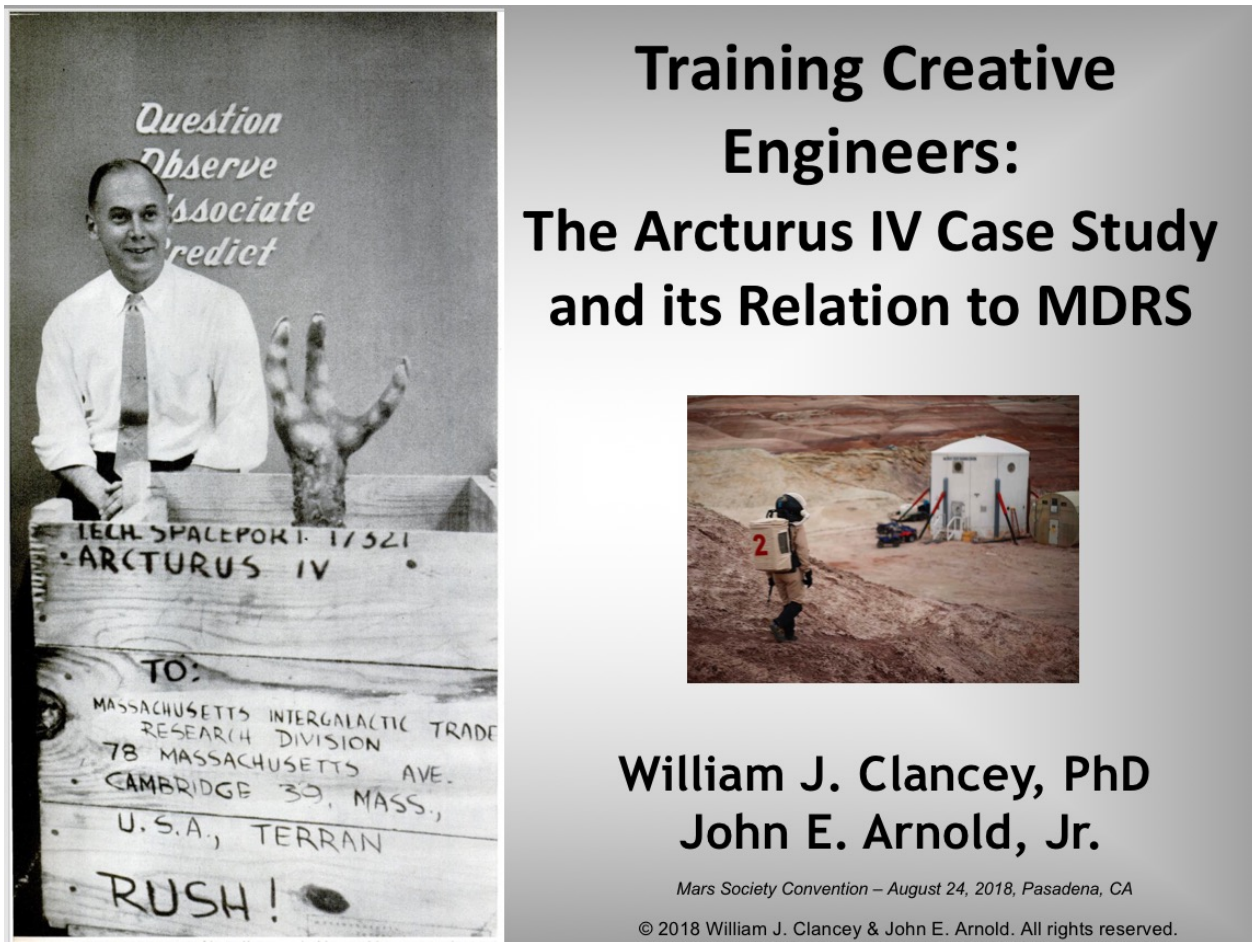


Figure 1. John E. Arnold in his MIT office, 1953. (Image credit: *Life Magazine*, 16 May 1955).

In this 1953 photo (**Figure 1**) you see Professor Arnold in his MIT office, surrounded by props from the case study. Apparently one of the alien beings has been shipped to the Massachusetts Intergalactic Traders (M.I.T.) to guide the design of suitable products. On the wall is his mantra for the creative process, a form of the scientific method. Arnold taught engineers that designing is not merely draftsmanship or prettying up a product for marketability. Designing is a creative

* This paper is an elaborated version of a presentation by the first author at the Mars Society Annual Convention on August 24, 2018 in Pasadena, CA.; first-person in the text therefore refers to the first author. Some of the slides have been adapted to present excerpts more completely in the main text, as the paper format allows. The second author is John E. Arnold's son; we have worked together throughout in rediscovering and publishing Professor Arnold's speeches and writings, notably *Creative Engineering* and *Arcturus IV*.

problem-solving process, which involves opening up your mind to think differently about challenging problems that matter for society.

THE ARCTURUS IV CASE STUDY

John Arnold died on sabbatical at the age of 50, having published only one magazine article and several conference papers. Consequently, apart from the many people he influenced in classes and seminars and through his business consulting, few engineers know about him today. But 50 years ago, he was a well-known teacher and leader in creative engineering. The *New York Times* on September 30, 1963 ran an obituary with a special addendum focusing on the Arcturus IV case study:

> **Methods Caused A Stir**
>
> Professor Arnold developed at MIT some highly imaginative classroom methods to stimulate creative thinking by his students. His "science fiction" approach caused a stir among traditional educators and conservative engineering leaders.
>
> The professor devised these unconventional methods as a result of his belief that the imagination can be trained by temporarily freeing students from their accustomed environment and placing them in a new imaginary one.
>
> For example, he would set up such fictitious situations as this: "You're living in the year 2953. Space travel is well established and there is a good deal of trade in the galaxy." He then would describe a special governmental bureau that had gathered information for use in trading with other planets. "The information is presented in the form of letters and special reports, printed on the prepared letterheads and forms of various fictitious agencies and people…." He commented that "this adds classroom realism."[1]

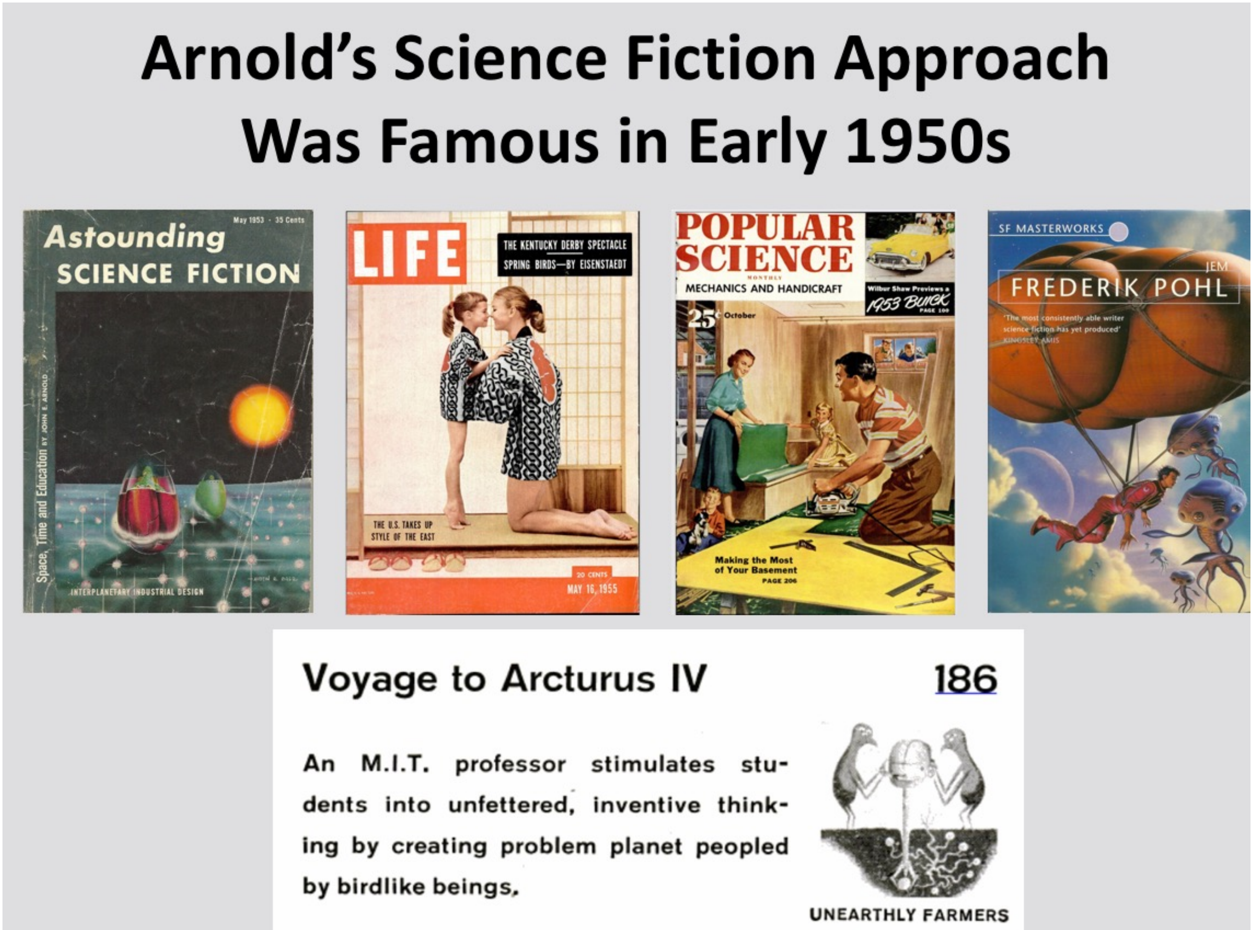


Figure 2. Three early articles described the Arcturus IV case study, leading to its fame; Pohl referred to it in his 1979 science fiction novel, *JEM*.

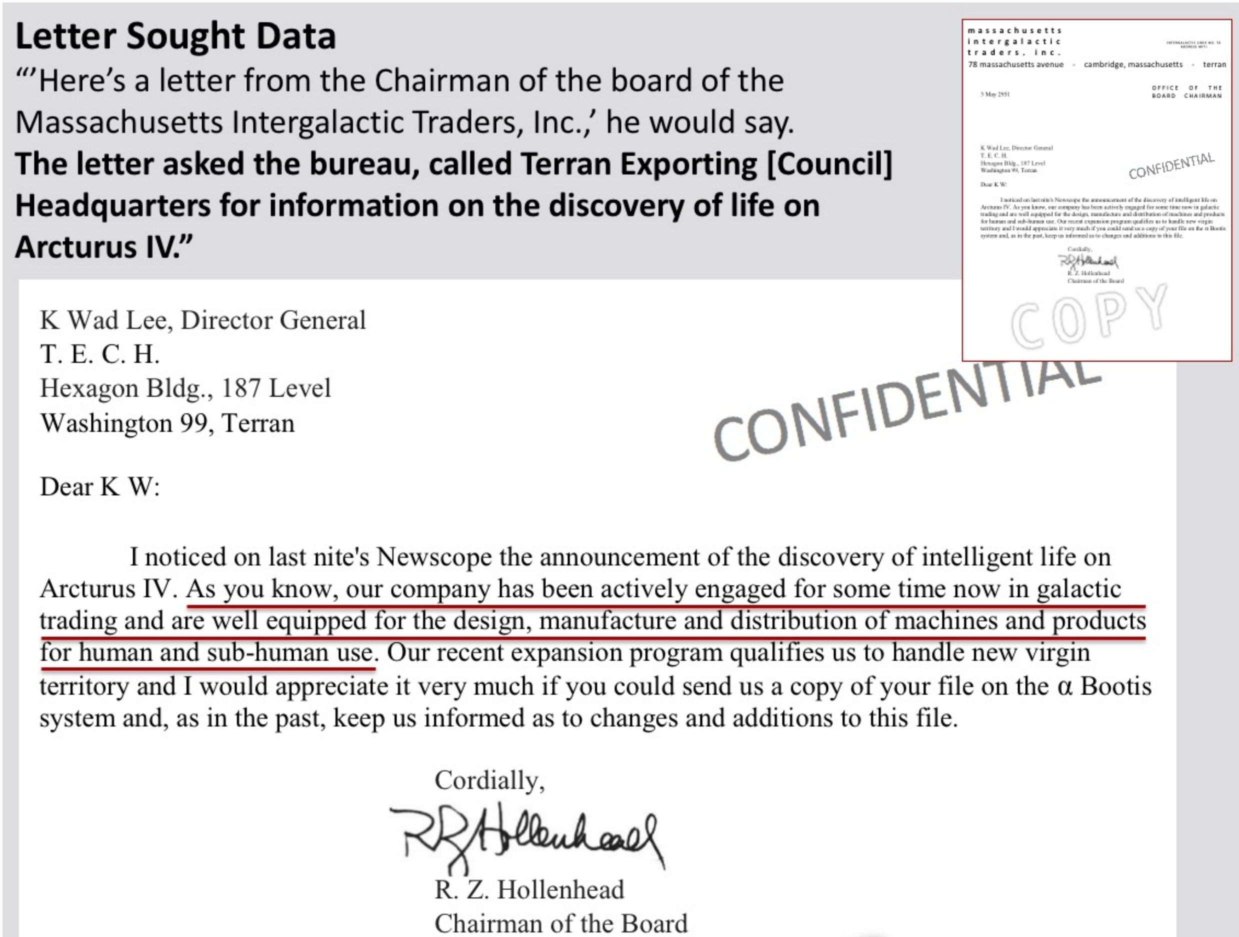
Arnold's feature article in *Astounding Science Fiction* in May 1953 described the Arcturus pedagogical approach.[2] *Life Magazine* May 16, 1955 ran a full-length story "Voyage to Arcturus IV" about Arnold, the course, and the effect on industrial design.[3] Another complete story ran in *Popular Science* October 1956.[4] Years later, Pohl in *JEM* refers to the 1950s design course and Arcturus case study (p. 74); he adopts the same trade-with-aliens storyline, "Well, the first thing is to figure out what their needs are" (p. 78).[5]

Figure 3. Excerpts from the *Life Magazine* (top) and *Popular Science* (bottom) articles.

Arnold's approach to design adopted a holistic perspective that relates physiology, psychology, culture, and the environment. It is a humanistic approach that designers call "empathy."

As a psychologist–engineer, Arnold grounded his philosophy of design in a theory of problem solving and learning. He believed creativity developed through self-knowledge. He taught engineers the psychology of design, showing how to generate ideas and the perceptual, cultural, and emotional blocks that inhibited imagination and play.

By these means he taught students to stop copying existing designs, to "lose earthly shackles."



Letter Sought Data

"'Here's a letter from the Chairman of the board of the Massachusetts Intergalactic Traders, Inc.,' he would say. **The letter asked the bureau, called Terran Exporting [Council] Headquarters for information on the discovery of life on Arcturus IV."**

K Wad Lee, Director General
T. E. C. H.
Hexagon Bldg., 187 Level
Washington 99, Terran

CONFIDENTIAL

Dear K W:

I noticed on last nite's Newscope the announcement of the discovery of intelligent life on Arcturus IV. As you know, our company has been actively engaged for some time now in galactic trading and are well equipped for the design, manufacture and distribution of machines and products for human and sub-human use. Our recent expansion program qualifies us to handle new virgin territory and I would appreciate it very much if you could send us a copy of your file on the α Bootis system and, as in the past, keep us informed as to changes and additions to this file.

Cordially,

R. Z. Hollenhead
Chairman of the Board

Figure 4. Continued description from the *New York Times* obituary, referring to Arnold's presentation to the class, with a letter addressed to T.E.C.H that he might have shown.

Arnold, here apparently under the guise of MIT Chairman R.Z. Hollenhead (**Figure 4**), orchestrated the Arcturus IV game, asking students to write memos providing information about the planet (**Figure 5**), which will be used for designing products for the beings there.

"A bureau file on Arcturus IV included a letter from the solar and galactic explorer who discovered the planet, and described the type of life found there.

The file also gave detailed information on the planet's size, density, temperature extremes, atmosphere, the length of the day and year and other data."

EXTRA-SOLAR PLANET REPORT

Terran Exporting Counsel Headquarters

SUN α Bootis **SPECTRAL CLASS** Ko **LUMINOSITY** 83X **MASS** 6×10^{33} grams

DIAMETER 19×10^{6} miles **SURFCE TEMP.** 4000° Abs **DISTANCE** 33 L.Y.

PLANET NAME Arcturus IV **NUMBER** IV **FILE NO.** 3463

FIRST CONTACT 22 January 2951 **BY** Gare E Toff

DISTANCE (from sun) 1800×10^{6} miles **MASS** 60×10^{27} grams **DIAMETER** 12×10^{6} meters

ACC.OF GRAVITY (cgs) 11,000 **SIDERIAL PERIOD** (Terran time) 49.4 years

LENGTH OF DAY (Terran time) 159 hours **DAYS IN YEAR** (Local time) 2720

MEAN TEMP. (Winter) -110° C **MEAN TEMP.** (Summer) -50° C

LIFE Intelligent sub-human **TRADE POSSIBILITIES** Excellent

REMARKS & FOLLOW-UP

1.) Atmosphere is largely methane and strangely enough the name of the local races translates to Methanian.

2.) State of Culture - early 20th century, say around 1905, America.

3.) Intelligent life extremely friendly. Quite short (height of male in picture 4'6") - apparently evolved from birds - covered with feathery type fur. - third eye seems to extend visual perception over much greater range than we are capable of. Hearing is much more acute in both high and low frequencies.

4.) Many different types of domestic animal life in evidence.

5.) Plant life is all low growing (similar to our mosses)and is apparently part of the root system of the plant. The edible portions of the plant are under ground at considerable depth. The blossoming and fruiting takes place underground, pollination being accomplished by worms similar to our earth worms.

6.) Due to high pressures, gravity and extreme cold the inhabitants move very sluggishly. This extreme slow pace is hard to adjust to.

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Received
Mass. Intergalactic Traders
17 May 2951

Figure 5. Continued description from the *New York Times* obituary (left); Extra-Solar Planet Report submitted to T.E.C.H. by the explorer, Gare E. Toff (right).

“The bureau then set up ‘Project Arcturus’ and sent out three groups of experts to learn more about the planet.”

T E R R A N
E X P O R T I N G
C O U N S E L
H E A D Q U A R T E R S

INTERGALACTIC CODE NO. 19
ADDRESS TECH

Hexagon Building – 187 Level – Washington 99 - Terran

20 March 2951

John A. Hrones was head of the Machine Design Division of the ME Dept—moved to Case Institute of Technology in fall 1957.

Memo To: J. H. Rones, Director of Engineering
J. R. Nold, Director of Design and Production
J. S. Wick, Director of Psychology & Physiology

Gentlemen:

Enclosed you will please find a copy of the letter from Gare E. Toff announcing first contact with the Planet Arcturus IV and his reports on the same. In accordance with established policy you will prepare plans for an immediate thorough investigation of this planet so that it can be announced to the public as soon as possible. Remember, of course, until public announcement is made, all plans must be kept perfectly secret.

Figure 6. Memo from K. Wad Lee, Director General of T.E.C.H. to M.I.T. Directors, establishing study requirements.

The memo in **Figure 6** established requirements for each department, reflecting a total-systems perspective that relates physical-environmental and psychological-cultural factors to technology (“material side”):

> Read the reports very carefully noting the extreme conditions existing on planet IV and make your plans accordingly. I would like to have a permanent Headquarters established and built as quickly as possible so sufficient men and supplies should be taken along for this purpose. At the same time a careful study of the physical aspects of the country and culture should be carried out by the General Engineering Group.
>
> The Psychological and Physiological group should make a complete survey of the animal and intelligent life so that we can advise all interested Terran trading companies. Do not, of course, overlook the spiritual, moral and psychological aspects of their culture and try to evaluate the effect of Terran contact on same. The Design and Production group should concern themselves with the material side of their culture so that we can lay out a program for a future trading program.

Arnold requested assistance from the MIT Science Fiction Society (MITSFS) in characterizing the planet's environment; this memo is dated four days after the first meeting. It appears that the month and day are when the memos were written, and 1000 years are added to the actual year.

Arnold had a particular interest in printing and likely typeset the memos himself. A few memos pre-date the meeting (**Figure 6** and **Figure 7**); they are possibly intended as a backstory about the discovery of the planet and the beings, which preceded the involvement of T.E.C.H. and subsequently the M.I.T. after the MITSFS meeting.

The names in the memos are often derived from students and professors who participated in the class. For example, J. R. Nold (Arnold) is Director of Design and Production. J. M. Swick in 1951 was a research assistant who apparently played the role of J. S. Wick, Director of Psychology and Physiology at TECH. Professor John A. Hrones was head of the Machine Design Division of the Mechanical Engineering Department; he moved to Case Institute of Technology in fall 1957.

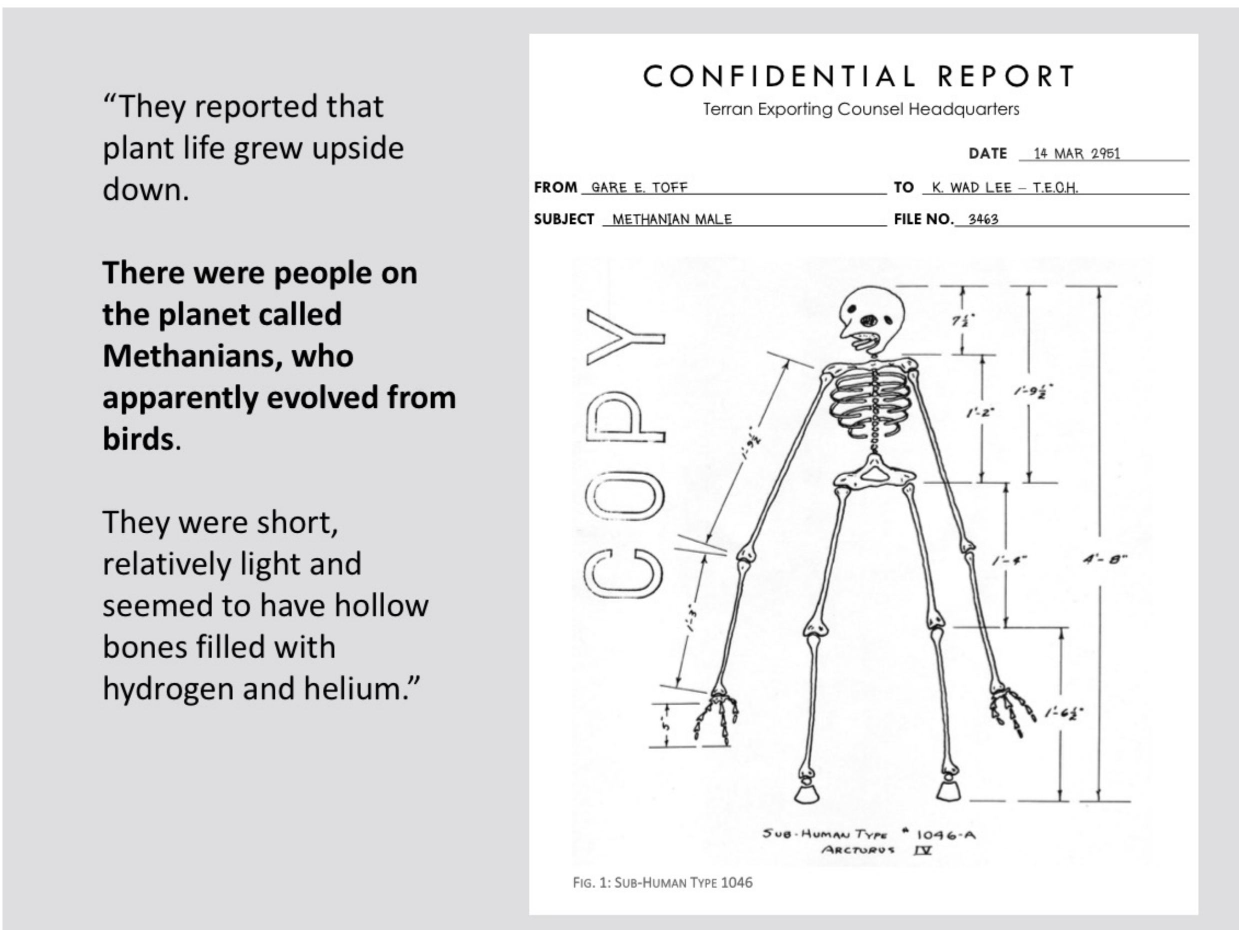

Figure 7. Continued excerpt from *New York Times*, with a page from the Arcturus IV Case Study.

"Economists of 'Project Arcturus' learned that the development of the planet resembled that of the United States in the early twentieth century. Electricity was used for light and power, but nothing was known of electronics. Trade opportunities appeared limited.

The Massachusetts Intergalactic Traders decided to start 'Project Dishpan' to make household articles for the Methanians. The students then were asked to design articles for this interplanetary trade."

Published: October 1, 1963

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massachusetts intergalactic traders, inc.
78 massachusetts avenue - cambridge, massachusetts - terran
OFFICE OF THE BOARD CHAIRMAN

20 August 2951

Mr. Arnold Edward
Chief Designer

Dear Arnold:

This letter is your formal authorization to proceed at once on design work for Arcturus IV. This will be known as "Project Dishpan" and expense should be charged to order No OK 2735. As you recall from our Department Heads Meeting your group is to prepare a number of Designs in the general fields of Household Products or Personal Use Products. All engineering details should be carefully worked out. S. Leare, Chief Engineer, assures me that his group will cooperate with you in every way to expedite the work.

Yours very truly,

R. Z. Hollenhead
Chairman of the Board

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CONFIDENTIAL

Dear Arnold:

This letter is your formal authorization to proceed at once on design work for Arcturus IV. This will be known as "Project Dishpan" and expense should be charged to order No OK 2735. As you recall from our Department Heads Meeting your group is to prepare a number of Designs in the general fields of Household Products or Personal Use Products. All engineering details should be carefully worked out. S. Leare, Chief Engineer, assures me that his group will cooperate with you in every way to expedite the work.

Yours very truly,

Figure 8. Conclusion of the excerpt from *New York Times* obituary, with a memo to M.I.T. Chief Designer, Mr. Arnold Edward from the Chairman of the Board, instigating the first design project.

The first Product design class to use the Arcturus IV case study focused on household products; this "Dishpan" memo was written August 20, 1951. The class apparently discussed the project in meetings, followed by exchanging memos to simulate communications in the M.I.T. organization of managers, directors and engineers. Thus Arnold was perhaps conveying how such projects might be managed in a corporation.

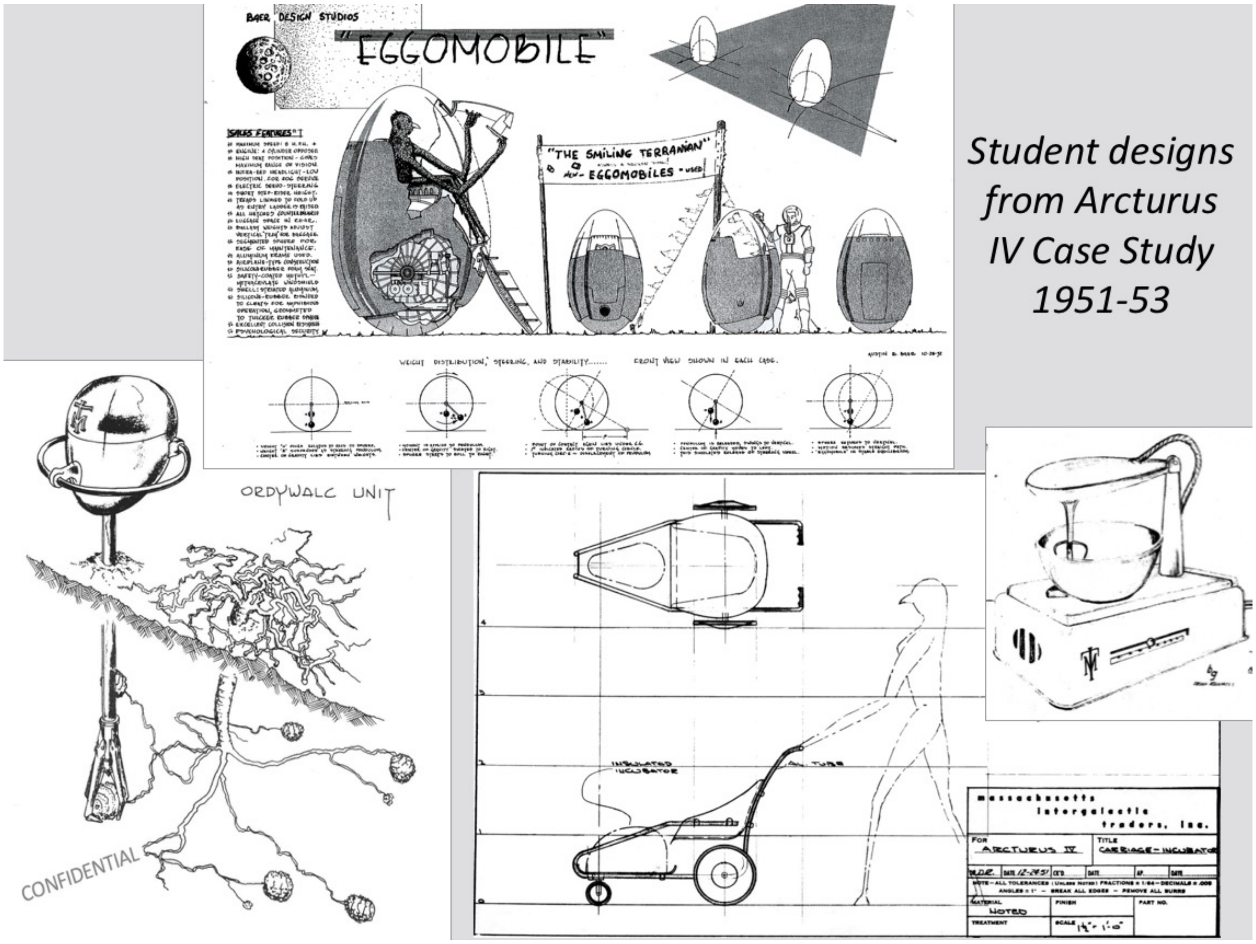

Figure 9. Student designs presented in memos included in Arcturus IV case file.

The students wrote memos to Arnold with their analyses and designs, serving as their Product Design project reports. Some of these diagrams were reproduced in the magazine articles, such as the Eggomobile: "Naturally, the egg shape should be an asset in selling the machines, since the Methanians are egg laying creatures, and this design suggests the protective security they enjoyed before hatching."[6]The Eggomobile diagrams with details (top) was conceived and drawn by the MIT architecture student, Austin Baer, who also painted the cover for the *Astounding Science Fiction* article. (After the course, Baer shifted his major to ME and had an illustrious career following and further developing Arnold's design theory and pedagogy; *Personal communication,* 25 February 2015.)

Figure 10. Arnold interacted with students and other guest speakers at meetings of the MIT Science Fiction Society.

As I mentioned, Arnold solicited help from the MIT Science Fiction Society to contribute to the Arcturus IV story. According to the minutes, saved in the MIT Library Archives, Asimov was present at the meeting that first discussed the Product Design course. (This is also the first time the MITSFS met as a formally recognized student organization.[7])

Notably, the Arcturus sector is mentioned on the first page of *Foundation*, a new novel that Asimov presented at the meeting. Arnold asked the MITSFS members for ideas for the story, evidently focusing on the extra-solar planet characteristics.

We do not know what aspects of the nature and life of the Methanians were first generated at this meeting or subsequently by MITSFS members, Product Design students and faculty, or Arnold himself. We do know that Arnold came into the meeting with the idea of a case study in which "students will design products for use in alien environments," intending the products to be used by alien beings on other planets.

Three years later at the MITSFS "freshman smoker" Arnold is the guest speaker: "He will speak on the development of the famed Arcturus IV Project in extraterrestrial design." The research biochemist and prominent science fiction author, Dr. Isaac Asimov, is described as another guest at the meeting.

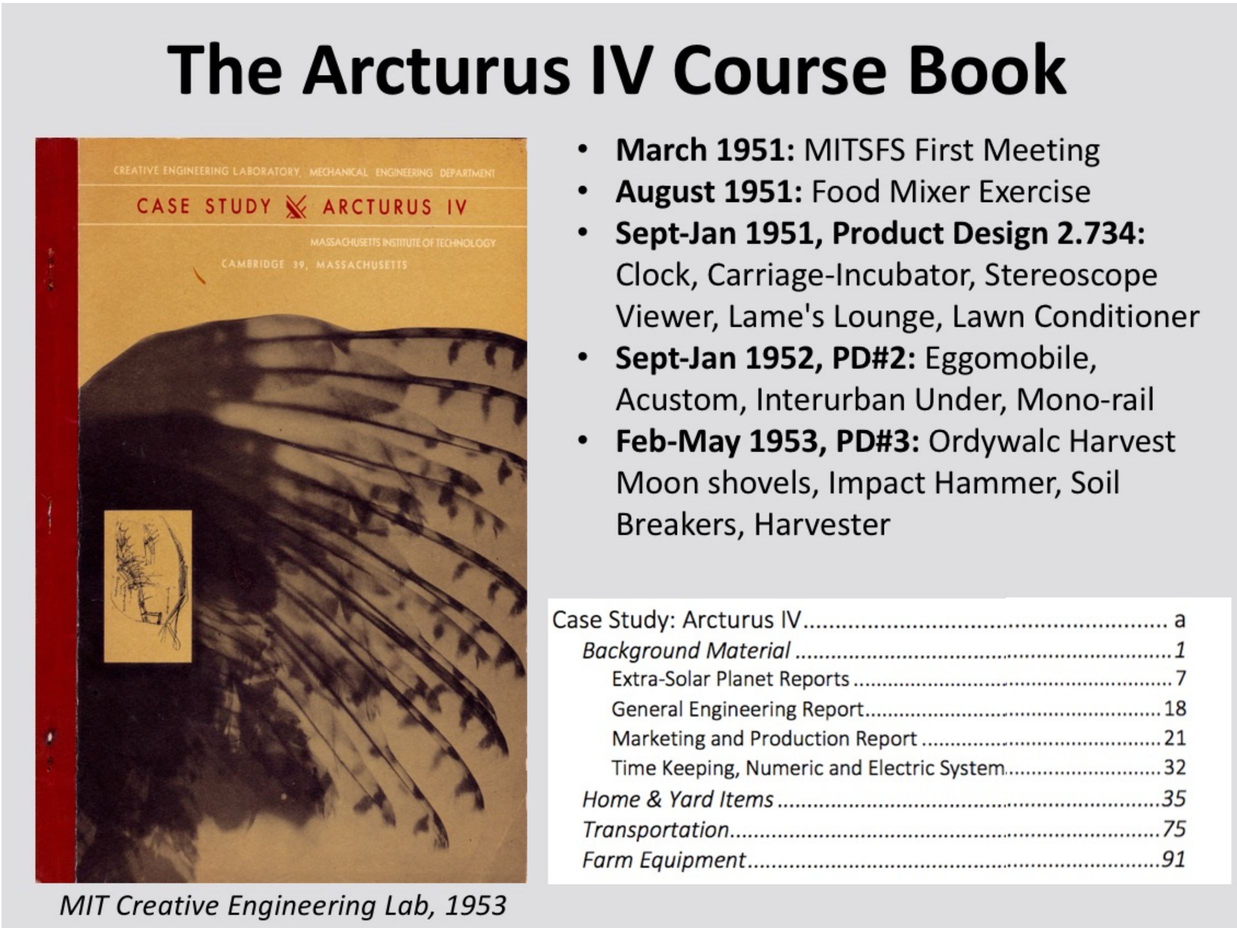

Figure 11. Original cover the Arcturus IV case study with key dates in development and contribution to the case study materials.

Case Study – Arcturus IV was published internally in 1953 as a technical report in the MIT Creative Engineering Laboratory. It collects "background material" and three years of course reports for Product Design, course number 2.734, a total of 113 pages. **Figure 11** lists the student projects; all the designs and associated memos have been reproduced in e-book format with an introduction and indices.[8]

Apparently the case study material was accumulated so students could refer to not only the background memos describing Arcturus IV, the Methanians, and the traders' project, but also prior class project designs, enabling them to learn about and mimic the genre, as they were tasked with designing different types of products for the alien beings.

ARNOLD'S APPROACH FOR TRAINING CREATIVE ENGINEERS

I'd like to shift now to talking more about Arnold's theory of design and then how that relates to MDRS. **Figure 12** quotes from Arnold's speech on creative engineering at a conference in 1955.[9]

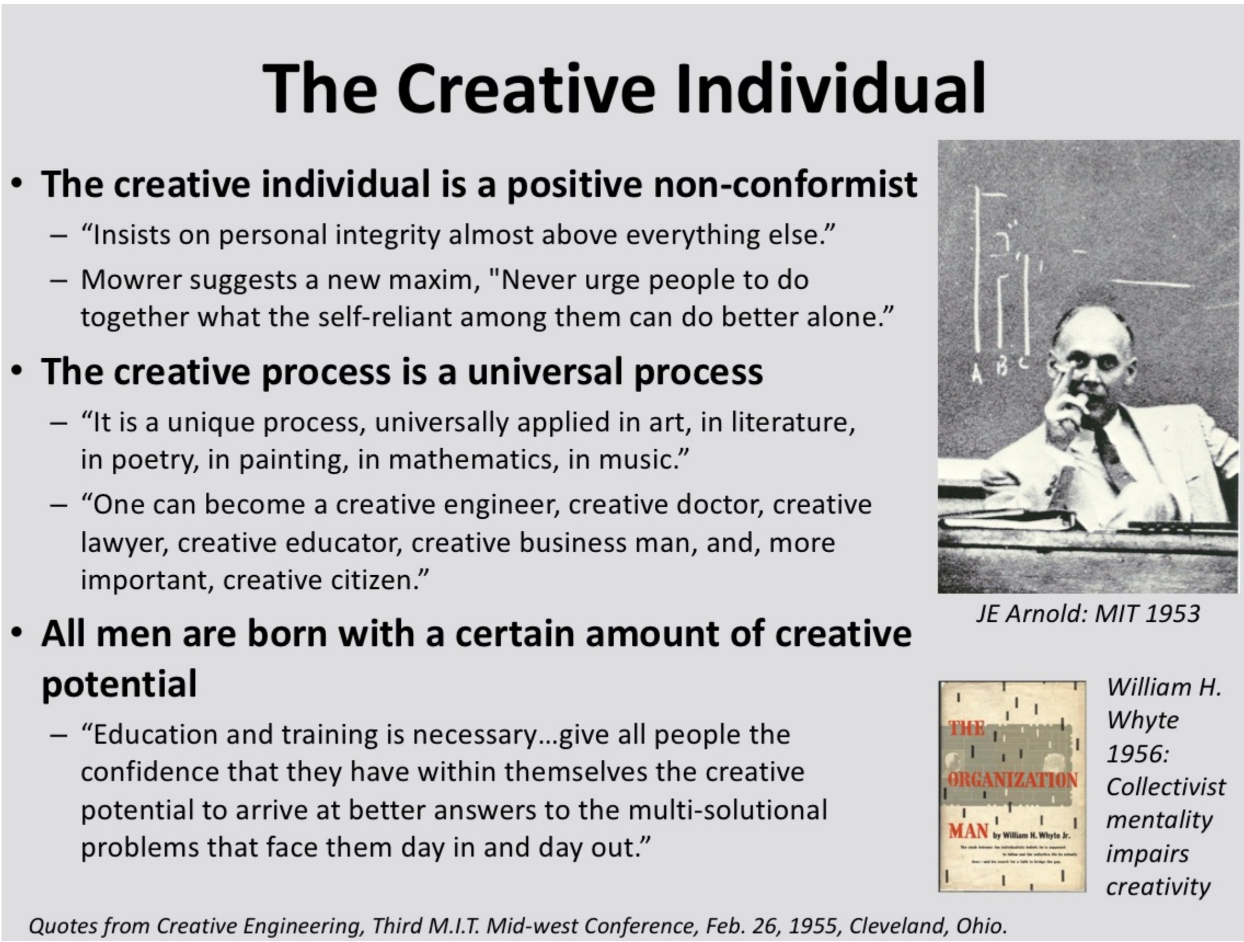

Figure 12. Remarks by John E. Arnold about creative engineering, 1955. (Image credit: Thomas Sheridan, *Industrial Design*, January 1957.)

Arnold's emphasis on creativity and individual integrity developed in part as a response to the Red Scare, the fear of communism in the 1950s. He referred in his speech to Mowrer's Saturday Evening Post opinion piece that had appeared earlier that month.[10] In Arnold's words, they were concerned about the "trend towards a 'herd' state which is being accelerated by those who incessantly insist that we all be integrated." Introducing his lecture on "Factors Influencing Creativity," he wrote: "I am sure that one of the reasons why there is an increasing interest in the creative process in certain circles today is that some people are becoming aware of the tremendous pressure that is being exerted on them to conform."[11] This is the image of cookie-cutter corporate workers marching into a factory, the era of "groupthink"[12] and Whyte's well-known book, *The Organization Man*.[13] The mantra was "Assimilate"—or as the Borg in *Star Trek* would say, "Resistance is Futile."

But Arnold and others resisted: He sought to spark an inner fire, inspiring a vision and confidence that you can change the world: “The creative process is universal”; “All men are born with creative potential.” He filled his talks with examples and ideas of inventors and psychologists such as Fuller[14] and Maslow[15] who spoke at his classes and motivational business seminars.

Figure 13. Arnold’s concept of the “creative engineer” synthesized leading ideas in psychology and engineering.

Arnold wanted engineers to work on challenging social problems. By his theory of design, creative breakthroughs required and promoted personal growth. Here he lists the qualities of a “comprehensive designer,” starting by orienting to people and their environment. You need to be able to relate ideas in different ways using the creative process deliberately and reflectively, and present your work confidently to others:

- **“Must be motivated by very broad concepts of human thought and behavior**; concern about the world's geographical and cultural groups; anticipate and predict the impact of designs.”
- **“Must adapt his creations to fit man**, rather than the other way around; become thoroughly familiar with the organism for which he is designing, and the total environment in which his product will be conceived, manufactured, sold and operated.”

- **“Must be articulate in all types and all levels of communication**; understand how one man communicates with another, or how a man communicates with a machine, or how one machine communicates with another machine.”
- **“Must maintain very delicate balance necessary in his ability to analyze, synthesize and to evaluate.** Great analytical ability without imagination or judgment leads to prosaic, common solutions.”
- **“Must have a complete understanding of and mastery in the use of the creative process.”**

Buckminster Fuller was Arnold’s colleague at MIT. Arnold combined Fuller’s systems-thinking, comprehensive design perspective for addressing large-scale social needs, with a psychological theory of creativity as problem solving. Studying and teaching creativity was apparently influenced by J. P. Guilford’s Presidential address[16] to the American Psychological Association in 1950; his “The Psychology of Thinking” is included in the readings for the 1957 Creative Engineering seminar.[17]

Arnold also incorporated Maslow’s notions of personal growth and actualizing the potential of the self, which Maslow presented during Arnold’s seminars, notably in “Emotional Blocks to Creativity,” included in the readings for the 1957 Creative Engineering seminar.[18]

Arnold’s emphasis on the individual, and particularly the remark from Mowrer that he quoted in his speech, is at odds with today’s established team-based design approach. A great deal can be said relating individual growth and teamwork. In particular, the individual–group opposition is misleading, as I discuss in detail in the Introduction to *Creative Engineering*. The example later in this presentation about our NASA research at MDRS and the experience of being a crewmember illustrates how the two perspectives on creative work can be reconciled.

LEGACY

Arnold’s approach is today called “Design Thinking.” His students and professor hires have transformed engineering (**Figure 14**).

Arnold transferred to Stanford University in 1957, under the aegis of the Provost, Frederick Terman, informally referred to as the “Father of Silicon Valley.”[19] Terman sought to transform engineering design at Stanford and possibly was encouraged by Arnold’s experience and reputation in business (indeed, he received a joint appointment as Professor of Business Administration at Stanford).

Arnold’s influence on the people he hired and their students is quite evident in their accomplishments. I mention them briefly here (by no means are these intended as career biographies); for more detail about their backgrounds and contributions see the Introduction to *Creative Engineering*.[20]

Figure 14. Arnold is credited as the progenitor of what is today called "design thinking."

- **Robert McKim** was Arnold's first hire; he was an industrial designer with an art background. As ME professor he emphasized prototyping and what he called "need finding," which related to understanding the people and their context (i.e., "understand the Methanians"). He wrote *Experiences in Visual Thinking*.[21] Today he is an artist living in Santa Cruz.
- **James Adams** was Arnold's PhD student; he had minored in art at UCLA. He became ME professor and incorporated many of Arnold's creativity exercises in *Conceptual Blockbusting*.[22]
- **Larry Leifer**, originally a surfboard designer, was to be Arnold's PhD student in Product Design in 1963. He formed the Center for Design Research in Stanford's ME Department, pursuing Arnold's partnership with corporations and interest in relating "design" and "science."
- **Bernie Roth** was hired as an ME professor in 1962; as of this writing he is still actively teaching at Stanford. His recent book, *The Achievement Habit*,[23] reflects his participation in the 1960s "Human Potential Movement." He and other Stanford professors collaborated with Werner Erhard at the Esalen Institute in Big Sur in the early 1960s.
- **David Kelley**, a student of McKim, co-founded IDEO (with his brother, Tom), the Palo Alto firm noted for designing Apple's computer mouse. Kelley and Roth co-founded the

Hasso Plattner d.School; its web page touts Arnold's mantra, "We believe everyone has the capacity to be creative."[24] The title of the Kelleys' recent book, *Creative Confidence*, strikingly fits Arnold's Arcturus IV pedagogy—instilling confidence to imagine and play, and hence to design creatively.

Figure 15. Viewing the Mars Desert Research Station (MDRS) as a facility–environment that enacts the story of designing for aliens, the future Martians.

PLAY AND IMAGINATION AT THE MARS DESERT RESEARCH STATION

By now you have probably seen the analogy with MDRS—in the Mars Society our concern is not Arcturus IV, but Sol IV. Rather than just asking engineers to design products for Martians on paper, at MDRS people role-play being on Sol IV, using their imagination to carry out a simulation of what living and working on Mars would be like. Thus we are enacting the very principle of Arnold's design method; we are bringing it to life.

Theories of learning and innovation have advanced a great deal in the past 60 years. In **Figure 15** I've described MDRS in terms used to characterize innovation, a combination of play and imagination.[25] As in world-building games, MDRS provides a fantastic place, a world of fantasy, that stimulates the imagination, opening our thinking to understand how the future setting potentially poses new kinds of problems and roles, procedures, tools, etc. that might be appropriate. It is a kind of "anticipatory design," carried out by projecting the self into the future by playing that part. MDRS provides an immersive experience, which facilitates reflecting on living and working practices, recognizing what is working well and analyzing what needs to be improved. The habitat, the crew's activities, and the surrounding landscape all reinforce the role-playing experience, as it continues all day for two weeks in MDRS rotations.

Third, borrowing from the analysis of world-building games such as *World of Warcraft*™, the "simulation game" played at MDRS creates a bounded learning environment—physically restricting the crew's living situation and where they crew can go outside (and preventing visitors), as well as constraining (through mutual agreement that may vary with crew objectives) the roles crewmembers play (e.g., "commander," "engineer," "biologist"), their activities, schedules, instruments/tools, and the procedures and practices they follow (particularly communication with the outside world). These "rules of the game" serve to guide the MDRS activity, while also giving meaning to and reinforcing the realism of "being on Mars."

Figure 16. Understanding NASA's Mobile Agents Project at MDRS (2002–2006) as a creative engineering activity.

Arnold's creative engineering approach gives us a different way of thinking about what my NASA Mobile Agents group did at MDRS and how the team was so successful.

In MDRS we have shifted world-building and role playing of Arcturus IV from only being a game using simulated memos to a design methodology that incorporates prototyping and experimentation in authentic settings. With today's technology, we are able to try things out early on, observe, raise questions, make predictions about new designs, and iterate. I've called this design process "empirical requirements analysis," because it grounds the imagination in facts and experience. Rather than just making up a story as in Arcturus IV, we are learning about actual needs while living and working in the Mars habitat and studying the analog landscape. This authenticity of the setting and activities reinforces the sense of significance and the serious purpose of the game.

Figure 16 relates to our experience using MDRS as an experimental setting for the NASA Mobile Agents project.[26] The project sought to develop "personal agents"—computer programs that interacted with people and each other—for astronauts on Mars. The first year (Crew 5 in April 2002) was exploratory, in which I learned as commander of a Mars Society crew what tools we might need, focusing on exploration outside (called Extravehicular Activities, EVAs).

During the following three years, the NASA Mobile Agents team incrementally developed a voice-commanding system that would make Mars astronauts more self-sufficient on EVAs—for safety (e.g., monitoring consumables and metabolic rate) and efficiency (e.g., for logging data, following a plan, and navigating).

Each year the NASA Ames and Johnson Space Center team met in September to sketch our vision for the next field season and possible technical methods. We then developed and tested the "agent–integration system" through the winter and early spring, going to MDRS in April or May to experiment with the new capabilities. I viewed the MDRS rotation as being like an "on location" movie production, leading to a video by the end of two weeks that showed the fully operational agent system being used by the two geologists to explore new areas around MDRS. In 2006 we shifted to developing agents for use by the crew inside the hab, in a system called "Power Agents".[27]

Recall the *New York Times* description of Arnold's pedagogy: "Imagination can be trained by temporarily freeing students from their accustomed environment and placing them in a new imaginary one." At MDRS we are learning not just how we will live and work on Mars—we are learning to be more creative by exercising our imagination in a free environment.

The openness of the landscape and our isolation opens our minds and spirits to having fun in everything we do. The dusty, hot setting was often difficult, and our technology rarely worked the first time—conditions in the wild are radically different from a laboratory. But we maintained a low-stress, "happy ship." Our isolation and the beautiful setting reinforced a positive, "can-do-it" attitude.

The bottom-right photograph in **Figure 16** shows Brent Garry and Abby Semple, the two geologists who explored the area around MDRS using the Mobile Agents EVA system. Their mock saber fight demonstrates how the experience of living and working at MDRS excites the imagination and playfulness. Every day they balanced the line between silliness and seriousness—somehow never quite concerned that they were wearing garbage can lids on their heads.

MDRS affords freedom of a special sort for adults in modern life: Freedom from overly scripted lives, institutional servitude, acting by rules and procedures that others must pre-approve or will supervise and evaluate. Stated more generally, at MDRS we are *training people to be creative engineers and scientists by freeing them from the shackles of organizational life*, just as Arcturus IV freed engineers in the 1950s from conventional formulaic analyses and designs and shifted their attention to "spiritual, moral and psychological aspects of [the Methanians'] culture."

NASA allowed, financially supported, and promoted our work at MDRS, but except for a visit on one day by the Deputy Director of NASA Ames, we were left alone. Management did not ask for plans or review what we were doing; we were trusted to work independently, and our accomplishments were plainly evident in the Mars Society's daily online reports, our publications, and videos. If this had been a NASA project at a NASA facility, the management hierarchy would have been engaged and other research groups at Ames Research Center in California or at Johnson Space Center in Houston might have competed for the right to work on our topic. At MDRS, we were free from the NASA bureaucracy, freed from what Arnold called *cultural blocks to creativity*. MDRS provided a safe haven for my group to do what it knew was right, and we were judges of our own progress and vulnerabilities.

Being at MDRS (or FMARS on Devon Island) instills in crews the courage of creative confidence, that our vision for bringing people to Mars will succeed. This shared passionate mission is the first step in being a creative scientist or engineer: Having learned about the Mars Society and observing its activities, we think, "I would like to do what they do; I would like to go to Utah." Thus a self-concept is born: "What I *could* do" becomes by participation, "What I *can* do" and that is "*Who I am.*" The image of the self expands from an initial conception, ideas about what you will do in the hab and on EVAs, to become a reality, an actual contribution on the team.

To become a crewmember, a person must establish that he or she has the knowledge and skills to make a difference during the rotation, living and working in the Mars analog setting. For each person, defining how you will contribute is the first creative step towards being there. Thus a relation is established among the Mars Society's mission, the niche or role the person realizes during a rotation, and the person's sense of identity. Interest, activity, and the self-image are mutually reinforced in the game of the Mars sim.

In summary, MDRS serves as a seed around which all the rest crystalizes—a provocative, isolated setting; affording an immersive experience; bounded by the simulation rules. In this learning environment individuals realize their potential by contributing. They create roles, schedules, procedures, tools, facilities, etc. for the Martians. By playing a part they create day to day, pretending to be on Mars, they become creative scientists and engineers.

READINGS FOR MORE INFORMATION

Some recent publications are available for learning more about the topics I have discussed.

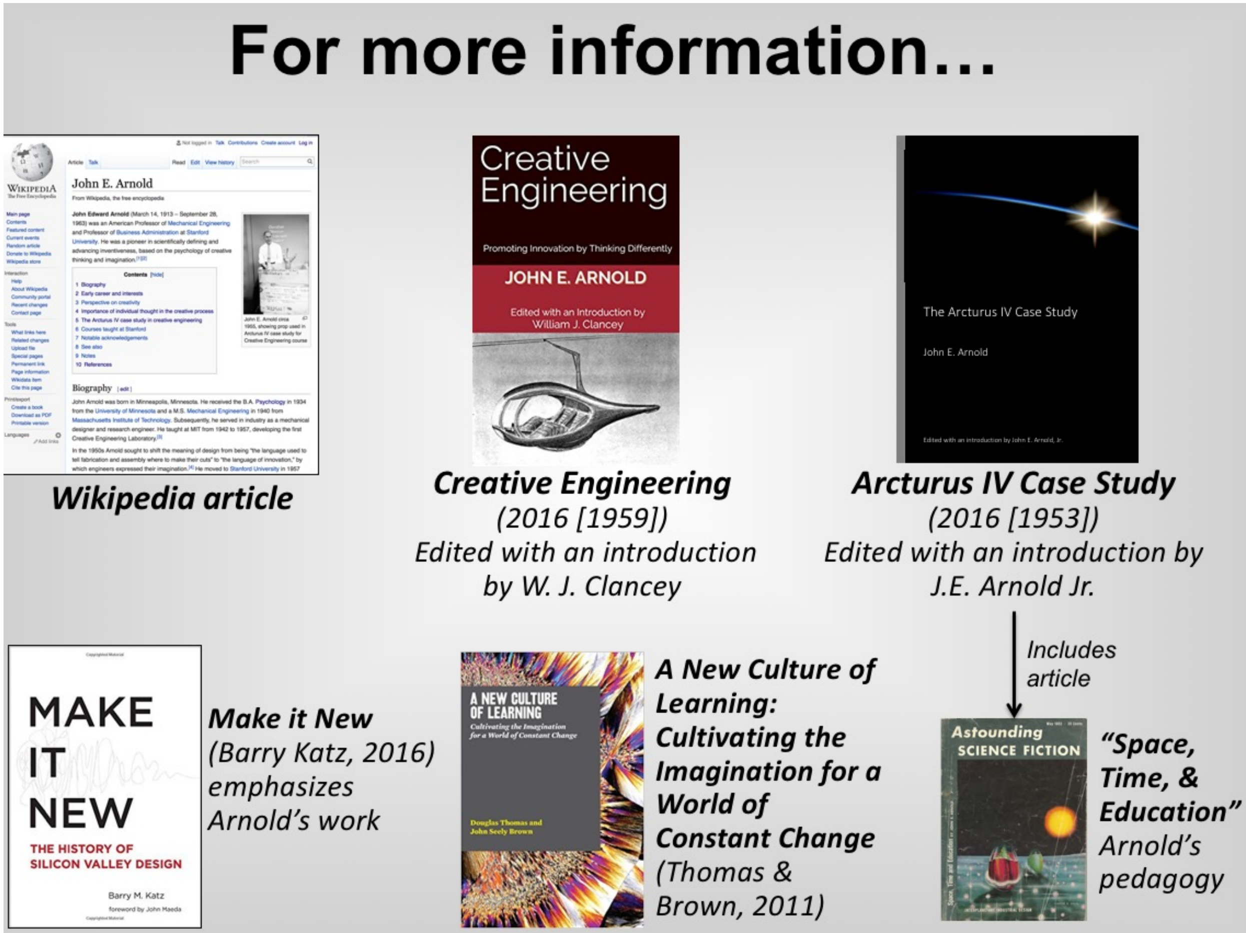

Figure 17. Recent publications for learning more about Arcturus IV and John E. Arnold.

For more information about John Arnold and his philosophy of design & pedagogy, please see my Wikipedia article.[28] John Arnold's son, Jack, is my co-author in this presentation today. He and I have edited and written introductions for two of his father's previously unpublished works–the Creative Engineering seminar and the Arcturus IV case study, which includes the *Astounding Science Fiction* article. These are available as low-price e-books.

You might also be interested in the book *Make It New*, which puts Arnold's work in the historical context of Silicon Valley.[29] And for more information about the perspective on innovation as relating play and imagination, see *A New Culture of Learning*.[30]

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