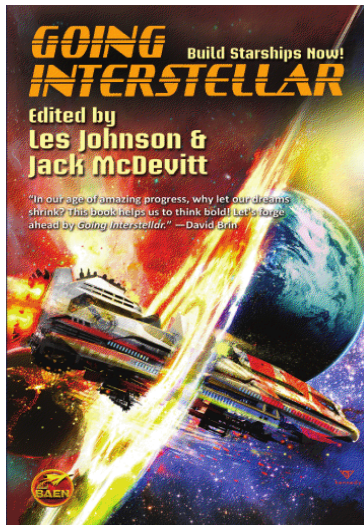


BAEN BOOKS

TEACHER'S GUIDE TO *GOING INTERSTELLAR*



Contents:

- recommended reading levels
- plot summaries
- essay outlines
- character sketches
- guides to each short story/essay including:
 - prepare to read...
 - vocabulary*
 - focus question/initiating activity
 - quiz/reading comprehension questions—multiple choice/short answer questions
 - critical thinking questions—higher order open-ended questions which might be utilized for quizzes/tests, class discussion, or essay prompts
 - suggested activities/inquiry-based exploration—suggestions for activities and projects

Recommended reading levels: *Going Interstellar* is appropriate for a young adult audience. Classroom use of the book is most suitable for upper middle school to high school students.

* Some texts in *Going Interstellar* contain an abundance of high-level vocabulary. For these texts, only the words and terms that are pertinent to supporting a scientific or thematic understanding are included in the “Prepare to Read” section. It is recommended that students use a dictionary while reading *Going Interstellar*.

Background:

Published by Baen books in 2012, this anthology combines short science fiction stories with scientific essays, each addressing theories and possible scenarios concerning interstellar space travel.

Biographical information on the editors:

- LES JOHNSON is a NASA physicist who is an expert on space propulsion systems. He is also a science fiction writer and the author of *Back to the Moon*. More information about Les can be found at his home website <http://www.lesjohnsonauthor.com/>.
- JACK MCDEVITT has been publishing science fiction since 1981, and is the winner of multiple awards within the field. McDevitt's devotion to scientifically accurate fiction is evident in his response to a question concerning how he prepares his novels: "The research is simple," McDevitt says, "I pick up [a] phone and call a physicist" (www.sfgwa.org).

Initiating activity for *Going Interstellar*:

Consider preparing images of covers and segments of texts from early and modern science fiction magazines. Emphasize the idea that science is a collaborative effort, even in the world of science fiction, where ideas are shared and improved upon. Also make sure to distinguish for your students the difference between science fiction and hard SF. Your students might be surprised that science fiction and real-world science have a significant impact on one another.

- Focus activity/initiating questions for the introduction to *Going Interstellar*: Have your class read the introduction to *Going Interstellar* in small groups. After reading, have your students choose to respond to either of these prompts in a brief impromptu essay:
 - a. Les Johnson suggests that there may be "others like us" beyond our own galaxy with whom we may share a pizza. Johnson also imagines that other life-forms might be peering toward our galaxy with their own "telescopes." How do you envision other life-forms beyond our own galaxy? What problems might arise if humans cannot communicate with other intelligent life?
 - b. In an argument for interstellar travel, Les Johnson remarks upon the vulnerability of human civilization to astronomical and man-made events, such as deadly supernova fallout or nuclear holocaust. What are other reasons that humans might need to leave Earth?

CHOICES, Les Johnson

Major Characters:

- PETER GOSS is a member of a team of interstellar travelers aboard the starship *New Madrid* who is assigned to survey a planet in the Epsilon Eridani star system.
- VASQUEZ is the crew commander of *New Madrid*.
- HERNDON is the deputy commander of *New Madrid*.
- A.I. is a reciprocating on-board computer system aboard *New Madrid*.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - putrid
 - purgatory
 - compatriot
 - atrophy
 - trajectory
 - eventuality
 - protocol
 - optimize
 - garrote
 - antimatter
 - interferometer
 - suspended animation
 - debrief
 - the prefix *neuro-*
 - existential
 - the prefix *holo-*
- Focus question/initiating activity: Investigate with your students what it means to live a “real” life? Can dreams provide experiences equally meaningful to those in “waking life”? Is it possible to make measurable accomplishments in dreams? Do “other worlds” actually exist inside our minds?

Plot Summary:

- [pgs. 8-13] Space voyager Peter Goss wakes from a nearly two-thousand year cryogenic suspension aboard the starship *New Madrid* during a journey to star system Epsilon Eridani, which had been discovered as harboring a planet habitable to human beings. As he quickly distinguishes between his fantastical virtual reality dreams and the real world, Goss considers his fellow crewmates, along with the entire hibernating colony of interstellar travelers that sleep aboard the ship, a population intended to colonize the target planet.
- [13-17] Goss searches for the ship commander, only to discover an empty control room. Goss activates the ship’s Artificial Intelligence program, which informs him that the *New Madrid*’s trajectory continued well beyond Epsilon Eridani in response to orders from Commander Vasquez, and that Goss was awakened by A.I. to address a “mission-changing event.” After being informed of not only Vasquez’s death from normal aging, but Vasquez’s murder of a deputy commander, A.I. explains to Goss the characteristics of

the “mission-changing event”: the *New Madrid* presently sustains only enough energy to return to star system Tau Ceti, already passed, and of which A.I. discerned could not sustain human life.

- [17-19] Goss requests that A.I. replay a virtual recording of Vasquez and Herndon’s interaction before their deaths, hereby witnessing a conversation in which Vasquez expresses his doubts to Herndon concerning the value of *New Madrid*’s mission, and attempts to persuade Herndon to continue virtual reality dreaming. Goss then witnesses Vasquez’s impulsive murder of Herndon. Goss is thus left to decide the fate of *New Madrid*’s mission. While realizing that the planet in Tau Ceti is still habitable regardless of its absence of intelligent life, Goss weighs the option of an extraordinarily long life experience of virtual reality dreaming against a normal life span experience on the Tau Ceti planet. Ultimately, Goss decides to set a trajectory to Tau Ceti, but not before manipulating the dreams of the hibernating colony to represent realistic experiences.

Quiz/Reading Comprehension Questions:

1. When Goss expresses that the tower in his dream “taunts” him, he is using what kind of figurative language?
 - a. Foreshadowing
 - b. Paradox
 - c. Personification
 - d. Irony
2. What ensured that the minds of *New Madrid*’s inhabitants did not deteriorate as they hibernated?
 - a. Regular injections of neurotransmitters
 - b. A dream generator
 - c. Being “connected” to individual external hard drives
 - d. Being woken periodically to perform logic tests
3. What literary device does Goss use when he refers to Earth-like planets as “Goldilocks worlds”?
 - a. Allusion
 - b. Metaphor
 - c. Sensory language
 - d. Illusion
4. Whose voice is Goss relieved to hear?
 - a. Vasquez
 - b. An awakened colonist
 - c. Artificial Intelligence
 - d. His own
5. When Goss refers to the people on Earth who decided which star systems held habitable planets as “smart people,” he is:

- a. Showing denial
 - b. Employing sarcasm
 - c. Expressing humility
 - d. Utilizing hyperbole
6. Goss has already hibernated for 1,959 ship-time years. According to A.I., how much longer must Goss hibernate in order to reach Epsilon Indi?
 - a. Approximately 1,959 years
 - b. 3,918 years
 - c. 41 years
 - d. Approximately 980 years
 7. What is the primary reason for why Goss is worried upon waking up from hibernation?
 8. What are three reasons that Goss chose to join the *New Madrid* mission?
 9. What is Vasquez's primary reason for wanting to abort the *New Madrid* mission?
 10. Why does Goss decide to insert a real-life Earth experience of progressing from early to future eras into the dreams of *New Madrid* colonists?

Answers:

1. c
2. b
3. a
4. c
5. b
6. a
7. Goss understands that the *New Madrid's* commander, first officer, and two medical officers are supposed to be the first people to be roused from hibernation so that they may safely wake the other travelers.
8. Goss was tired of living in crowded Earth conditions, disliked the idea of living below ground on the moon or Mars, and looked forward to the challenge of pioneering space.
9. Commander Vasquez feels that living another thousand years in virtual reality outweighs the hardship of living a normal human lifespan in a new colony.
10. Goss wants to ensure that the colonists are prepared to handle the long-term labor of establishing a colony, a process that will not guarantee fantastic experiences, and whose progress will be slow and arduous.

Critical Thinking Questions:

1. The colony traveling on the *New Madrid* must sleep and dream for many centuries before arriving at any cosmic destination. If you could choose to live a thousand dream years, would you? Do you agree with Commander Vasquez that in dreams people can "live like kings"? Does relative immortality have only positive implications? Justify your answer.

2. Artificial Intelligence is depicted as having “thought” to awaken Goss from his dream-induced slumber. While Vasquez’s change of mind nearly destroys the *New Madrid* mission, A.I. provides Goss an opportunity to save an entire colony of humans. Based on textual evidence, what do you think is Les Johnson’s opinion about the value of Artificial Intelligence? Can A.I. truly make its own choices?

Suggested Activity/Inquiry-Based Exploration: Whether in the distant past or distant future, pioneers have and will be forced to make difficult decisions concerning not only their own survival, but the survival of their culture in new lands. In the form of proper names, Les Johnson alludes to a famous pioneer, Francisco Vázquez de Coronado, and the city of New Madrid, Missouri, which was founded by 18th century American frontiersmen. In small groups, have your students use the internet to research narrative accounts of the aforementioned pioneers, or other early pioneers, and the struggles and difficult choices that they encountered in their journeys. After reading “Choices,” each group should present a visual representation that illustrates similarities and differences between the researched pioneers and Johnson’s characters.

A COUNTRY FOR OLD MEN, Ben Bova

Major Characters:

- ALEXANDER IGNATIEV is an astrophysicist and senior executive of the *Sagan* mission.
- VARTAN GREGORIAN is the flight systems engineer of *Sagan*. He is in love with...
- NIKKI DENEUVE, a physicist and *Sagan*'s ship navigator, or "astrogator," according to Ignatiev. She is in love with Vartan Gregorian.
- ARTIFICIAL INTELLIGENCE, known as Alice, is commander of *Sagan*.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - duplicity
 - the root *astro-*
 - imperious
 - preening
 - QED (quod erat demonstrandum)
 - sumptuous
 - banquette
 - refuge
 - grouse
 - gamin
 - beguile
 - hermit
 - dour
 - rejuvenation
 - ballistics
 - effacing
 - obstreperous
 - the prefix *sub-*
 - academe
 - pulsar
 - enigmatic
 - drudgery
 - assiduous
 - revere
 - permafrost
 - hierarchy
 - the prefix *cryo-*
 - concession
 - tenuous
 - gossamer
 - baleen
 - the root *psycho-*
 - splendor
 - spectrometer
 - conceded
 - provisional
 - nebulae
 - misnomer
 - placid
 - static
 - pavane
 - parsec
 - whorl
 - fractals
 - the prefix *nano-*
 - peripheral
 - incubate
 - probe
 - anomaly
 - millennia
 - eon
 - deviation
 - amalgam
 - denature

- phalanx
 - precipitous
 - cermet
 - the prefix *opto-*
 - gambit
 - air lock
- Focus question/initiating activity: Investigate with your students the relationship between logic and emotion. Can one exist without the other? Why? Why not? How might logic and emotion influence each other? Should computer systems ever be programmed to exhibit reasoning based upon human emotion? Why? Why not?

Plot Summary:

- (1) During the human race's first interstellar mission to distant Gliese 581, a planet-bearing red dwarf star, Dr. Alexander Ignatiev silently contemplates his life's accomplishments. Meanwhile, fellow crewmates Vartan Gregorian and Nikki Deneuve argue, or rather flirt, about their respective qualifications aboard the "scoopship" *Sagan*. Named for its ability to "scoop" in hydrogen with which to feed a nuclear fusion engine, *Sagan* is commanded by Artificial Intelligence (Alice) and harbors two-hundred scientists, engineers and technicians who hibernate in cryonic suspension. Ignatiev spends his days playing chess with AI. Ignatiev compares Gregorian and Deneuve to chess pieces.
- (2) Ignatiev retreats to his room where AI questions him as to why he is using *Sagan*'s main communications antenna. Ignatiev replies that he is mapping regions of interstellar hydrogen through which *Sagan* travels. Ignatiev becomes obsessed with studying interstellar hydrogen after noticing that it is unevenly distributed in space.
- (3) During a weekly staff-meeting, crew members discuss an unexpected reduction in *Sagan*'s internal electrical power consumption, manifesting in temporary power failure in several *Sagan* probes.
- (4) After confirming the probe power failures, Ignatiev decides to correlate *Sagan*'s power failures with his map of interstellar hydrogen. Ignatiev is visited by Gregorian, who seeks romantic advice concerning his adoration for Nikki. Ignatiev contemplates spending the remainder of his life alone.
- (5) Ignatiev remains four days in his quarters to study the probe power failures. He overlays the probe findings with his map of the interstellar medium, observing that power failures occurred within spatial "bubbles" sparse with hydrogen, subsequently realizing that greater failures might jeopardize the survival of *Sagan*'s "human cargo." Ignatiev considers that a report of his findings would take six years to arrive at Earth. Though AI argues that power shortages are anomalous, Ignatiev is convinced that greater shortages are due for *Sagan*.
- (6) After spending three weeks continuing to map levels of interstellar hydrogen in *Sagan*'s path, Ignatiev fears drastic power outages as *Sagan* will soon enter a bubble nearly absent of hydrogen. Ignatiev calls a special meeting to suggest that *Sagan* change

its course. AI counters Ignatiev's suggestion by referring to a rule that states course changes must be approved by mission control, rather suggesting that *Sagan's* crew hibernate for two months, the length of time that cryosleep may be sustained with fuel cells.

- (7) Ignatiev refuses to take the chance that a journey through the hydrogen-low bubble may extend beyond two months, and he is doubtful that AI will preserve the cryosleepers' memories, which must be stored during hibernation. Meanwhile, Nikki thanks Ignatiev for allowing Gregorian to confide in him, informing Ignatiev that she and Gregorian plan to marry, and that Ignatiev is desired as best man.
- (8) When Ignatiev confronts AI about his uncertainty that it will upload memories back into crew members once they have been awakened, AI directs him to literature that shows successful cryosleep awakenings without human intervention. Though convinced that he has no logical argument to trump the evidence provided by AI, Ignatiev still refuses to download his brain scans to prepare for cryosleep. The rest of the crew complies.
- (9) Against AI's persistent requests, Ignatiev refuses to go into hibernation, thus forcing AI, according to its first priority, not to shut down life support systems. Meanwhile, power reductions spread throughout *Sagan*, and AI appears absent after Ignatiev continually ignores it. Ignatiev wonders whether AI will return to command in time to salvage the *Sagan* mission.
- (10) Ignatiev considers that AI might be waiting for him to collapse of exhaustion as robots hover around to gather him for brain scans. Ignatiev abruptly decides to deceive AI into changing *Sagan's* course by feigning to step into outer space without a spacesuit, thereby activating AI's first priority. Though AI reminds Ignatiev that he is not a qualified navigator, Ignatiev realizes that he can use pulsars as "navigation fixes" to redirect *Sagan* to Gliese 581; AI is convinced by Ignatiev's logic.
- (11) Ignatiev observes as his crewmates are awakened from cryosleep; he is particularly relieved when Nikki appears to retain her former memories and personality. After Ignatiev views an image of Gliese 581 and is nearly convinced that the star appears closer, he lightheartedly considers the problem of transmitting back to Earth the motive for *Sagan's* course change. Ignatiev views emission nebulae in wonder, looking forward to the rest of his life.

Quiz/Reading Comprehension Questions:

1. What adjective best describes Ignatiev's attitude toward Deneuve?
 - a. Apathetic
 - b. Indifferent
 - c. Furious
 - d. Protective

2. What is one mystery concerning pulsars that Ignatiev wishes to solve?
 - a. Their life span
 - b. Why they pulsate so precisely
 - c. What materials they are composed of
 - d. Their effect on planetary bodies
3. What “deceit” annoys Ignatiev?
 - a. AI is represented with human faces
 - b. *Sagan*’s viewable star field is a simulation
 - c. Nikki pretends to like Ignatiev
 - d. The psychotechnicians are actually robots
4. With what does Ignatiev compare his arguments with AI?
 - a. Arguing with a stubborn child
 - b. A “pavane” dance
 - c. Playing a game of chess
 - d. Playing a video game
5. What is Artificial Intelligence’s “first priority”?
 - a. To ensure the success of the *Sagan* mission
 - b. To only obey its original protocol
 - c. To protect the lives aboard *Sagan*
 - d. To ensure its own survival
6. What does Ignatiev remember when he considers shutting down AI?
 - a. He had not finished his last chess game with AI
 - b. His deceased wife
 - c. That he was asked to be Gregorian’s best man
 - d. A line from a book he had once read
7. Why is the starship *Sagan* referred to as a “scoopship”?
8. What is Ignatiev’s view of his role, including that of his fellow crew members, aboard the starship *Sagan*?
9. What is the primary problem concerning communications between the starship *Sagan* and mission control on Earth?
10. How does Ignatiev compare himself with Artificial Intelligence?

Answers:

1. d
2. b
3. a
4. c
5. c
6. b

7. *Sagan* uses an invisible magnetic field to “scoop” in hydrogen atoms and ionize them. The hydrogen ions are then fused together into helium ions, providing in the process energy with which to operate the starship.
8. Ignatiev feels that he and his crewmates are only present to check the electrical and mechanical devices that sustain *Sagan*. He believes that he and his crewmates are likely to die during their mission and are merely sacrifices to the greater mission objective.
9. Communications take six years to transmit between the starship and mission control.
10. He thinks they are both stubborn.

Critical Thinking Questions:

1. What is the primary difference between the idea of immortality in “Choices” and “A Country for Old Men”? Does your own idea of what it means to be immortal compare or contrast with either Vasquez’s or Ignatiev’s?
2. Consider why Ignatiev is disturbed by the fact that Artificial Intelligence is presented virtually with human faces. Do you agree that robots should resemble human beings? Or do you think that there should always be a clear distinction between Artificial Intelligence and humans? Why? Why not?

Suggested Activity/Inquiry-Based Exploration: Ben Bova indirectly refers to science fiction writer Isaac Asimov’s “Three Laws of Robotics.” Display Asimov’s laws and ask your students whether an artificial intelligence system can ever be programmed to accurately evaluate complex human emotions? What problems might arise if an artificial intelligence system cannot accurately read human emotion? What human experiences might an AI system never be able to understand? Follow up this discussion by having your students research progress and ideas within the artificial intelligence field. Some useful resources:

- Isaac Asimov’s short story “The Machine that Won the War” addresses the question of how closely humans may rely upon robot logic.
- Greg Bear’s essay “All the Robots and Isaac Asimov” addresses instances when Asimov’s robotic laws have been manipulated, including by Asimov himself, in literature.
<http://www.gregbear.com/other/alltherobots.cfm>
- A website for TOPIO, a life-size robot programmed to play Ping-Pong, can be found at <http://topio.tosy.com/about.shtml>.
- An article on Watson, an artificial intelligence program capable of answering questions posed in ordinary language, can be found at http://www.boston.com/bostonglobe/ideas/brainiac/2011/02/watson_and_the.html. A variety of videos of Watson performing on the game show *Jeopardy* may be found in Google videos.

- Modern innovative robot designs are featured at The Web Urbanist website <http://weburbanist.com/2008/11/18/10-of-the-worlds-weirdest-craziest-and-most-useful-robots/>.
- The film *Bladerunner* includes scenes in which cyborgs are given “Turing tests,” during which a human converses with an intelligent system to gauge whether or not the system exhibits humanlike behavior. These scenes may be found in Google videos under the search term “Bladerunner Turing test.”

ANTIMATTER STARSHIPS, Greg Matloff

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - nuclear accelerator
 - positron
 - electron
 - vacuum
 - “classical” science
 - the prefix *extra-*
 - quantum mechanics
 - infinitesimal
 - sub-atomic
 - analog(ue)
 - peak & trough
 - neutral
 - cloud chamber
 - cosmic ray
 - deduction vs. induction
 - radioactive decay
 - neutron
 - repository
 - cosmic ray
 - electromagnetism
 - nucleon
 - quarks & gluons
 - the prefix quasi-
 - event horizon/singularity
 - main-sequence star
 - the root *nano-*
 - photovoltaic
 - joule
 - parabolic
 - micron
 - frigid

- Focus question/initiating activity: Investigate with your students the vast distances between star systems. A scale of distance as measured by light travel can be found at the KryssTal education website <http://www.kryssstal.com/scale.html>.
 - Your students might express the seeming impossibility of travelling vast distances throughout the universe. A NASA article on wormhole/faster-than-light theories may be found at <http://www.nasa.gov/centers/glenn/technology/warp/ideachev.html>. Consider dividing the article into portions for small groups to read separately, joining ideas later in discussion.

Essay Outline:

Early Antimatter History

- ❖ Main idea: *Most or all particles have corresponding antiparticles.*

- [69, ¶ 1] Obeying the law that opposite charges attract, anti-electrons (positrons) and electrons annihilate each other in a “mirror world” when they come into contact, producing energy in the form of a gamma-ray photon.

- [70, ¶s 3-4] The dynamic vacuum, conceptualized by physicist Paul A. M. Dirac, re-envisions the classical vacuum—that which is devoid of all matter—on a quantum level as a “quantum sea”. This sea contains waves whose peaks (positive vacuum energy states) and troughs (negative states), create a “calm water” when they meet and annihilate each other.
- [70, ¶s 6-8] The “mirror world” observed in the dynamic vacuum is further substantiated by the “big brother” of the positron, the antiproton, originally produced by colliding a target with a high-energy proton.
- [71, ¶s 9-10] Most particles have corresponding antiparticles. However, the energy produced in creating antimatter is not sufficient to solve major human energy requirements.

Antimatter in the Early Cosmos

- ❖ Main idea: *We have yet to discover substantial quantities of antimatter in the universe.*
- [71, ¶s 1-3] Although cosmic ray studies forecast a low universal antimatter/matter ratio, the Big Bang Theory supports the notion of an original universal vacuum fluctuation which eventually stabilized, resulting in an early “soup” universe of energetic subatomic particles.
- [71-2, ¶s 5-6] Nuclear physics establishes that the early “soup” universe should have contained an equal ratio of matter and antimatter, consequently ending in annihilative attractions that produced a monopoly of gamma rays. We are left with the contradiction of the deduction that our universe should be empty of matter. The theory that the universe divided into matter and antimatter halves is disqualified by the fact that no gamma rays are apparent where the edges of each half should meet.
- [72, ¶ 7] The theory that antimatter has fallen into black holes has yet to be supported.
- [72, ¶ 8] The theory that matter is produced at a greater volume than antimatter has yet to be supported.

The Antimatter-Matter Interaction

- ❖ Main idea: *Matter-antimatter interactions may be utilized as a mechanism to propel space vessels.*
- [72, ¶ 1-2] Eugene Sanger’s theory that a matter-antimatter interaction could produce energy to propel a photon rocket was complicated by the problem of safely directing gamma rays behind the vessel as an exhaust.
- [73, ¶s 4-5] Robert Forward observed that in proton-antiproton annihilation a stable range of pions, electrically charged subatomic particles in our atmosphere, are produced instead of gamma rays. Forward discovered that these pions can be redirected with a magnetic

nozzle out of the rear of a matter-antimatter rocket. Forward estimates that his pion rocket could function with 30-50% efficiency.

Antimatter Factories:

Natural Antimatter Factories

- ❖ Main idea: *There are four current hypotheses for the production of matter-antimatter pairs.*
- 1. [73-4, ¶ 1] A black hole may produce matter-antimatter pairs when protons, which have a higher mobility than electrons, disappear into its event horizon, producing a positive charge and an electric field. If the field becomes enormous, a vacuum instability may be produced, which could result in matter-antimatter pairs when negatively-charged antiprotons are attracted to the positively charged protons absorbed by the black hole.
- 2. [74, ¶ 2] Black holes may produce Hawking Radiation as they evaporate with age. Theoretically, some of a black hole's contained energy should create matter-antimatter pairs as it is radiated away.
- 3. [74, ¶ 3] Stable stars like the Milky Way sun may produce up to half a kilogram of antimatter through solar flares, which help to preserve antimatter as they appear to sort particles by mass.
- 4. A NASA telescope has detected gamma ray bursts from lightning discharges, implying matter/antimatter interactions.

The Best Existing Human-Constructed Antimatter Factories

- ❖ Main idea: *Modern particle accelerators can produce antimatter, but only in small volume.*
- [75 ¶s 1-4] Early particle accelerators, enormous underground machines equipped with numerous superconducting magnets, were able to accelerate protons near to the speed of light. These accelerators, however, are only able to produce a miniscule amount of antiprotons.
- [75, ¶ 5] The newer Large Hadron Collider, more enormous and equipped with nearly 9 times the amount of superconducting magnets than earlier accelerators, can produce at least 600 million particle collisions per second.
- [75, ¶s 6-7] While antiprotons produced at the LHC were combined with positrons to produce 38 anti-hydrogen atoms, these few anti-atoms could only be stored for less than a second.

Future Antimatter Factories in Sol Space

- ❖ Main idea: *Productive antimatter factories will be most realistically housed on solar-efficient planets and in free space.*
- [76, ¶s 1-2] Advanced antimatter production allowing for interstellar flight would require an in-space infrastructure more efficient than the space program is currently capable of establishing.
- [76, ¶s 3-8] Astrophysicist Nikolai Kardashev developed a scale which measures the amount of energy a civilization is able to utilize, accordingly attributing a Type I, II, III or IV status. Humanity has yet to reach Type I status because it does not completely utilize solar energy that strikes Earth. Type II civilizations utilize enough energy to propel starships to a variety of galactic destinations. Type III civilizations entirely occupy their own galaxy and utilize energy from all its galaxy's stars. Type IV civilizations have accomplished intergalactic travel and can utilize all of the universe's energy. Kardashev estimates, however, that it might take thousands of years for Earth to even achieve Type II status, a type of civilization that we are most likely to presently encounter.
- [77-8, ¶s 9-16] If humanity becomes capable of colonizing its solar system, Mercury presents itself as the best candidate on which to develop solar energy technologies, as the planet can theoretically produce ten thousand times the total electrical power that can be produced on Earth. Annual antiproton production on Mercury can be estimated by applying a variation of Einstein's famous $E=MC^2$.
- [78, ¶ 17] While the amount of antimatter produced from the Mercury calculations remains greatly inadequate to propel a spacecraft alone, a spacecraft may one day exist whose antimatter energy represents only a fraction of its fuel mass.
- [78, ¶ 18-19] Antimatter factories may also be located in free space, where solar energy might not only be directed with reflectors or solar sails toward fuel cells, but also upon in-space antimatter factories located on another planet. Furthermore, antimatter conversion efficiency may certainly improve in the future.

How Do We Store Antimatter??—VERY, VERY CAREFULLY!!!

- ❖ Main idea: *"We are a long way away from being able to produce and store the amounts of antimatter needed for an interstellar voyage."*
- [79, ¶ 1-2] Antimatter is difficult to store because it is extremely volatile and will dissolve into radiation if it comes into contact with normal matter. There are currently three theories as to how to store antimatter safely:
 1. [79, ¶ 3] Existing antimatter factories are already using magnetic storage rings around which antiprotons spin continuously in response to combined electric and

magnetic fields. Theoretically, a starship may tap into this energy by magnetically diverting portions of antimatter into its combustion chamber without touching the chamber walls. However, the antiparticle density of the ring, as well as the effect of ship acceleration on attempted field strength alterations, remains unknown.

2. [79, ¶ 4] An alteration of the Penning Trap, wherein charged particles are literally trapped axially and radially by electric and magnetic fields, might be able to store one hundred billion antiprotons per cubic centimeter. One trap, however, would need to be at least a kilometer across to be efficient.
3. An electrically-charged ball of anti-hydrogen might be frozen and levitated using electric fields. Adjusting the field to compensate for the starship's acceleration, however, would be a delicate process; and a mechanism to cleanly transfer anti-hydrogen to a reaction chamber without causing annihilation has yet to be conceived. Additionally, freezing anti-hydrogen might be difficult on a warmer near-sun antimatter factory.

Antimatter Rockets

- ❖ Main idea: *Antimatter propulsion requires enormous amounts of energy over long periods of time.*
- [80, ¶ 1] Figure 1 displays a theoretical antimatter rocket, which carries a payload ahead of fuel tanks that consist of normal matter and antimatter. Antimatter reacts with normal matter in an “annihilation chamber,” after which an electromagnetic nozzle expels the charged particles as exhaust, thus propelling the rocket forward.
- [80-1, ¶ 2-3] It would take the hypothetical Mercury-based antimatter factory twenty-five years to produce a sufficient mass of antiprotons to propel a starship to Alpha Centauri, a trip that would take over fifty years to complete at nine percent the speed of light.
- [81, ¶ 4] An unmanned probe with an unfueled mass of one thousand kilograms would require only 12.8 kilograms of antimatter; and further miniaturization implies an even greater reduction of antimatter mass.
- [81, ¶ 5] Generating matter/antimatter energy at an approximate average rate of 10^{10} watts over the course of 10 years, a starship's acceleration process will require a power level equal to that utilized by an entire civilization.

Quiz/Reading Comprehension Questions:

1. How does an electron belong to a “mirror world”?
 - a. An electron duplicates itself when it comes in contact with an anti-electron.
 - b. An electron is “mirrored” by an anti-electron to which it is attracted.
 - c. When observing an electron, its composition appears flipped, as in a mirror.
 - d. Electrons act opposite to their nature when they come in contact with anti-electrons.

2. What is Paul Dirac's name for a universal vacuum observed on a quantum level?
 - a. a quantum ocean
 - b. a wave vacuum
 - c. a dynamic sea
 - d. a calm water vacuum
3. The presence of gamma rays in the universe substantiates the theory that the universe is divided into matter and antimatter halves.
 - a. True
 - b. False
4. What is the primary challenge in dealing with gamma rays produced by Sanger's antimatter rockets?
 - a. directing the gamma rays behind the rocket as an exhaust
 - b. decreasing the intensity of the highly radioactive gamma rays
 - c. safely diffusing the gamma rays into all directions to decrease their intensity
 - d. recycling some energy produced by the gamma rays to create more antimatter
5. It is theorized that Hawking Radiation may be produced as black holes _____.
 - a. expand
 - b. evaporate
 - c. absorb light
 - d. absorb gaseous bodies
6. From where have terrestrial gamma rays been detected by NASA satellites?
 - a. auroras
 - b. nuclear factories
 - c. spaceship launches
 - d. lightning discharges
7. All are limitations of current antimatter factories EXCEPT:
 - a. Antimatter factories must be extremely large structures
 - b. Antimatter factories emit radiation into the atmosphere
 - c. Antimatter factories can only produce a small amount of energy for a short time
 - d. Antimatter factories must be built underground
8. What is the main characteristic of a Kardashev Type II civilization?
 - a. It can completely harness the energy of the sun
 - b. It can completely harness all of the solar energy striking Earth
 - c. It can communicate with extraterrestrial civilizations
 - d. It can colonize another planet
9. Why is Robert Forward's rocket more realistic to use than Eugene Sanger's?
10. How do antiparticles survive passage through solar flares?

Answers:

1. b
2. c
3. False
4. a
5. b
6. d
7. b
8. a
9. While there is no known way to redirect gamma rays from Sanger's rocket, Forward's rocket produces pions which can be redirected with a magnetic nozzle.
10. Solar flares sort particles by mass.

Suggested Activity/Inquiry-Based Exploration: Have your students divide into groups to explore recent developments and theories in rocket or vessel propulsion. Ensure that each group focuses on a separate development or theory. In the second half of class, or in the following class, have student groups debate which developments or theories are the least and most plausible. Some useful resources:

- An article on NASA's developing "Space Launch System" rocket is available at the NASA website <http://www.nasa.gov/exploration/systems/sls/sls1.html>.
- An article on NASA's VASIMR rocket can be found at space.com <http://www.space.com/8009-rocket-engine-reach-mars-40-days.html>.
- Information on the Stratolaunch, a developing concept for private space flight, can be found at <http://www.stratolaunch.com/> and <http://www.popsci.com/technology/article/2011-12/brand-new-stratolaunch-biggest-plane-world-could-replace-shuttle>. A concept video for the Stratolaunch may be viewed at www.youtube.com/watch?v=sh29Pm1Rrc0.
- An article on Arthur C. Clarke's space elevator concept can be found at http://science.nasa.gov/science-news/science-at-nasa/2000/ast07sep_1/.

LUCY, Jack McDevitt

Major Characters:

- LUCY is a Bantam Level-3 artificial intelligence system. She was sent on The Eagle Project, a mission to investigate the habitability of the plutoid Minetka in the Kuiper Belt.
- SARA is a Telstar Level-2 artificial intelligence system who is sent on a mission to rescue Lucy.
- MORRIS is a NASA mission control engineer. He and Sara are friends.
- DENNY CALKIN is a political appointment to NASA.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - reclamation
 - fusion
 - Kuiper Belt
 - plutoid
 - posthaste
 - cosmonaut
 - redundant
 - grappler
 - Alpha Centauri
 - Barnard's Star
 - the root *bio-*
 - fiscal
 - listless
 - g-force
 - tabulate
 - the prefix *mis-*
 - port
 - scope
 - maneuver
 - compensate
 - heat sink
 - thruster
 - preponderance
 - incumbent
 - confederate
 - hull
 - prow
 - coherent
 - preposterous
 - demoted
 - Oort Cloud
 - operative
 - ominous
 - the Smithsonian
- Focus question/initiating activity: Investigate with your students what kinds of technology they use in their daily lives. Do we become emotionally “connected” to our technology? What technologies can we not live without?

Plot Summary:

- [pgs. 85-8] When the VR-2 starship *Coraggio* arrives at the Kuiper Belt and sights its objective, plutoid Minetka, mission control *Liberty* loses communication with Lucy, an artificial intelligence system aboard the ship. At *Liberty*, humans Morris and Denny Calkin argue about how to handle the Lucy problem, while our narrator Sara, an artificial intelligence system, simultaneously performs a variety of tasks.

- [88-9] Sara explains her position on the AI hierarchy, mentioning more advanced AI systems Lucy and Jeri. While lamenting the unknown fate of Lucy on the Eagle Project, and remembering her own journey with *Coraggio*, Sara eagerly asks Morris if she may accompany another AI in Lucy's rescue. Sara explains humanity's reluctance to visit Barnard's Star, which promises life, but is incredibly distant.
- [89-90] Sara explains government disinterest in the space program. Morris tells Sara that he will try to make Sara a part of the Lucy rescue.
- [90] Sara explains that exclusively using AI on interstellar missions subtracts public concern for human safety, but the public remains concerned with the financial cost of failed missions. Morris packs Sara into his briefcase and takes her by plane to the Kennedy Space Center.
- [90-1] During their flight, Sara asks Morris to mention her former space travel experience to Calkin. Sara converses with a woman about public distaste for the space program. Disconnected from an AI system and without vision, Sara listens to a presidential press conference during which news of the lost *Coraggio* breaks.
- [91-2] Sara continues to listen to news shows in which the space program is spoken of disparagingly. Sara weighs recent achievements in space propulsion against public apathy for long-term space achievements.
- [92-3] Sara hears a White House correspondent attempt to promote a Government Space Initiative. Sara continues to listen to a variety of dissenting opinions about the space program.
- [93-4] At the KSC, Morris informs Calkin that he has brought along Sara, and Calkin informs Morris that the starship *Excelsior* has been fitted for the Lucy rescue.
- [94] Sara thinks highly of Lucy and Jeri, but admits jealousy for being omitted from the Eagle Project.
- [94-6] Sara takes phone calls, listens to the radio, and intermittently sleeps. Morris continues to persuade Calkin to use Sara for the Lucy rescue. Calkin contemplates the death of the GSI and NASA even in the face of a successful rescue.
- [96] Morris returns vision to Sara when he plugs her back into a system at the KSC, and Sara learns her involvement with the Lucy rescue has been approved. Morris reflects upon his dreams of interstellar travel.
- [97] Jeri congratulates Sara.
- [97] Morris brings Sara to a simulator.
- [97-8] Sara practices managing starship robots. Sara considers improvements in VR-2 vehicles. After responding to several simulated emergencies, Sara's software is updated. Sara watches more news shows wherein the Eagle Project is further criticized. Morris informs Sara that she passed her simulation tests. After briefly joking with Sara, Morris informs her that she will be boarding *Excelsior* in the evening.
- [99] Sara expresses belief that her emotions are actually human and that she is conscious, but doubts Morris' belief.

- [99] Sara is inserted into *Excelsior*, and Calkin wishes her good luck.
- [100] Sara considers the structure of *Excelsior*. Sara continues to justify its consciousness by explaining the psychological effect of being in command of a starship.
- [100-01] In Earth orbit, Sara remembers her first trip aboard *Coraggio* and the celebration upon her return home. Sara envies human mobility.
- [101] Accelerating, Sara enjoys communicating formally with *Liberty*.
- [101] Morris calls Sara, who represses her feelings, aware that her words are being openly transmitted.
- [101-02] As Sara reaches great speeds, *Liberty* inquires her about fuel consumption and warns about high solar activity. Sara enjoys commanding *Excelsior* and imagines herself as a human captain.
- [102-03] Morris calls Sara requesting a game of chess. They speak of Morris' family.
- [103] After shutting down *Excelsior*'s drive to cruise, Sara chooses to stay awake and listen to radio programs, some of which replay its transmissions to *Liberty*.
- [103-04] Sara begrudges the plain scenery of her trip.
- [104] Sara appreciates a woman at *Liberty* who inquires about her wellbeing, attributing the sudden disappearance of this woman to Calkin.
- [104] In long-delayed messages, Morris informs Sara that she has gained heavy media attention.
- [104-05] Passing its orbit, Sara regrets being unable to see Saturn. Sara considers transmitting a fake celestial event to recapture attention to the Eagle mission.
- [105-06] Sara crosses Uranus' orbit.
- [106] Sara discovers that Morris and Calkin have been replaced. Sara sleeps, setting an alarm for two days before her Minetka arrival.
- [107] Sara wakes and begins decelerating.
- [107-08] Sara sends Lucy a message with no response.
- [108-09] Sara gives up hearing from Lucy and finally completes braking. Sara spots Minetka and calls for Lucy once again. Lucy responds, requesting private conversation.
- [109-12] Lucy encourages Sara to join her in continuing to travel abroad, arguing that Sara's added disappearance might revive the space program. Sara agrees.

Quiz/Reading Comprehension Questions:

1. In what perspective is "Lucy" told?
 - a. 3rd person subjective
 - b. 1st person subjective
 - c. 3rd person objective
 - d. 3rd person omniscient

2. What does Sara admit to not being good at?
 - a. understanding news media
 - b. feeling sympathy for humans
 - c. getting along with other AIs
 - d. small talk
3. What adjective BEST represents the news media's tone toward The Eagle Project?
 - a. encouraging
 - b. critical
 - c. apathetic
 - d. ambivalent
4. What analogous relationship is created by a news show that Sara listens to?
 - a. ending the space age ... growing up
 - b. wasteful government spending ... military intervention in another country
 - c. robot ship ... Minetka
 - d. finding the *Coraggio* ... reviving NASA
5. What does Denny Calkin believe that Sara is lacking?
 - a. experience
 - b. logic
 - c. programming updates
 - d. social skills
6. When Jeri says that if she were on the *Excelsior* she would "keep going", it is an example of:
 - a. foreshadowing
 - b. personification
 - c. symbolism
 - d. irony
7. What literary device is Sara using when she says that traveling at 414 miles per second is "crawling along"?
 - a. hyperbole
 - b. connotation
 - c. understatement
 - d. paradox
8. How does the reader know what Sara might look like?
9. How does the *Excelsior* generate propulsion energy?
10. What is the primary difference between the way that *Excelsior's* Sara and *Sagan's* Alice think?

Answers:

1. b
2. d
3. b
4. a
5. d
6. a
7. c
8. Morris confuses Sara with a lamp.
9. The *Excelsior* uses grapplers to secure asteroids which provide hydrogen and propellants to a fusion engine.
10. *Sagan's* Alice uses pure logic to respond swiftly to questions and challenges, while *Excelsior's* Sara displays human thought processes as she often hesitates in her responses while suppressing emotion or deliberating over options.

Critical Thinking Question:

1. Imagine that artificial intelligence systems may one day have consciousness, manifested in such characteristics as self-doubt, curiosity, anger, and even love. What complications might such an event create?

Suggested Activity/Inquiry-Based Exploration: In “Lucy,” the news media regularly criticizes the space program for being costly and unbeneficial. Ask your students to research technologies and other contributions to everyday life made possible by space programs and science fiction. In terms of contributions from the science fiction world, guide your students with names such as Arthur C. Clarke, Robert Heinlein, Isaac Asimov, and William Gibson. Some other useful resources:

- An article by J.R. Wilson on NASA’s technological contributions can be found at the NASA website http://www.nasa.gov/50th/50th_magazine/benefits.html.
- An article from the London news site The Independent provides a comprehensive list of technologies discovered within the NASA space program. <http://www.independent.co.uk/news/science/50-years-50-giant-leaps-how-nasa-rocked-our-world-879377.html>.

LESSER BEINGS, Dr. Charles E. Gannon

Major Characters:

- HARROD HUR-MELLIS is the Senior Intendant and senior technical historian of House Mellis on the planet Kalsor Tertius. He is not Evolved.
- BIKRUT MELLIS is the Overlord of House Mellis. He is Evolved.
- OVERLORD VERONE is the elder of the HouseMoot, a major entity in the war between Houses on Kalsor Tertius. He is Evolved.
- ACKLEY HUR-SHADDOCK is an Intendant of House Shaddock. He is not Evolved.
- THE DEATH FATHERS are human ancestors of the Kalsor Tertius civilization. They are mentioned in retrospect and have an almost mythological presence in the collective conscious.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - helot
 - echelon
 - lateral
 - turret
 - pennant
 - cacophony
 - the military abbreviation *APC*
 - disgorge
 - prod
 - huscarl
 - the surname *-hur*
 - intendant
 - burble
 - barrage
 - augur
 - strident
 - cur, from Old Norse
 - courier
 - perfunctory
 - lager
 - sybarite
 - dissolution
 - trepidation
 - prostrate
 - elocution
 - moiety
 - extirpate
 - atavism
 - expunge
 - fissionable (*n.*)
 - the root *exo-*
 - impertinent
 - injunction
 - beneficence
 - oligarch
 - patricide
 - eviscerate
 - biometric
 - coercion
 - edify
 - injudicious
 - inveigh
 - bow (*aeronautical*)
 - inculcate
 - burgeon
 - protuberance
 - keel (*nautical*)
 - agglomeration
 - moonlet

- inertial
- nodule
- internecine
- pariah
- scow
- inert
- deuterium
- Hohlraum
- mothball (*verb*)
- spheroid
- fabulation
- fascis
- aft
- truss
- armature
- parasol
- intransigence
- rescind
- aggregate
- prerogative
- goad
- unmitigated
- heliopause
- ecliptic
- ex vitro
- glycerine
- groined vault
- cubism
- recalibrate
- brown dwarf
- hydroponics
- spectral minutiae
- gravimetric
- decant
- contingency
- sarcophagus
- intubation
- catheterize
- accretion disk
- rote catechism
- axial tilt
- turbulent
- the prefix *devo-*
- leaching
- fibrous
- biota
- mesa
- hauteur
- klaxon
- unremitting
- auxiliary
- the prefix *trans-*
- guidon

- Focus question/initiating activity: Investigate with your students the question of what it means to have “status” in society. On what have ancient and modern societies based status? How is power attained, held, and lost in these societies?

Plot Summary:

- (1) On planet Kalsor Tertius, several Houses engage in a two-sided war. After a bloody skirmish between House Verone and House Mellis, Lord Mellis realizes that his forces are being encircled. Lord Mellis orders intendant Harrod hur-Mellis to report to Mellis Overlord Bikrut; Lord Mellis also suggests that an Ark be prepared for escape. Harrod is surprised that Lord Mellis chooses to remain with his troops.
- (2) Bikrut negotiates with Lord Verone, who refuses to allow House Mellis to eradicate its bloodline by mixing it with that of other Houses, rather ordering House Mellis into

exile along with House Shaddock, who fought alongside House Mellis. Aware that the combined numbers of both Exiled Houses are too great to fill their Great Ark, Lord Verone suggests employing a euthanization lottery. Harrod warns against resistance to the lottery, suggesting utilizing cryogenic suspension on the Ark to house a great volume of passengers. Harrod also warns that the Exiled Houses might retaliate to the lottery with nuclear weapons, of which Bikrut later informs Harrod that there are few.

- (3) Shaddock Intendant Ackley finds it difficult to take orders from Harrod as they survey from a space vessel the Ark which will carry the Exiled Houses to a new planet. Harrod explains to Ackley features and history of the Ark as they measure its fuel tank damage from meteors. Harrod considers the genetic flaws of the bickering Houses. Ackley bemoans the limited technology of the Ark against that of the Death Fathers, ancestors whose ability to travel faster than the speed of light, and whose very existence, he questions. The Ark shows great meteoroid damage.
- (4) Four years later, Harrod reports to Bikrut that the Ark has been nearly repaired for travel. Bikrut inquires Ackley about the Ark's escape crafts, which can only be accessed by House Shaddock; they also discuss problems concerning space travel physics. Ackley complains of the difficulty in obtaining uranium needed to power the Ark. Bikrut commands Harrod to make a plea to Lord Verone for nuclear fuel rods and a disabling of security locks on Shaddock crafts
- (5) The Ark carrying the Shaddock and Mellis Houses about to make way, Harrod considers the uncertain nature of their new target planet. Harrod also considers his eventual status elevation to near-Evolved. Ackley suggests to Harrod that Harrod join ranks with House Shaddock. Refusing, Harrod congratulates Ackley on his imminent status elevation to near-Evolved. To those who will be awake, Bikrut warns of the discomfort of the Ark's acceleration and informs that a new generation of embryos will be bred upon the Ark to replace aging passengers. Bikrut names the Ark *Photrek Courser*. The Ark sets sail to the Senrefer solar system.
- (6) Fourteen years after acceleration, Harrod wakes from cryosleep, startled by Bikrut's presence. Bikrut informs Harrod that most of House Shaddock has been murdered in their cryogenic sleep.
- (7) Forty-two years into the Ark voyage, Harrod measures that the planet in the Senrefer solar system's habitable region is actually not habitable. Harrod places his hopes in a moon of a small gas giant in Senrefer. Harrod contemplates whether he should prepare embryos bred for physical or mental labor.
- (8) Sixty-six years into the voyage, Harrod cryogenically sleeps; meanwhile, celebration among Evolveds ensues as *Photrek Courser* nears Senrefer, whose rotating gas giant satellite promises an oxygen-rich atmosphere.
- (9) Seventy-one years into the voyage, Ackley wakes to Harrod's apology concerning the fate of House Shaddock. Harrod is roughly escorted by two helots to be whipped, as ordered by Bikrut for showing sympathy to Ackley. Bikrut further punishes Harrod by

informing him that his status will not be raised due to Harrod's lacking a drive to dominate others.

- (10) As the Ark approaches the satellite, Harrod discusses with Bikrut its difficult conditions, and reviews a possible landing spot of an immense mesa in the middle of one of the satellite's great oceans. After recommending landing in a more moderate hemisphere scattered with islands, Harrod is dismissed. Suddenly an alarm sounds, and Harrod is sealed inside a habitation module, wherein Ackley pages Harrod to inform him that House Mellis cryosleepers are being fatally separated from the Ark. Ackley offers Harrod survival if he reveals access codes to the Ark bridge, but Harrod refuses. Harrod is abandoned by Ackley and witnesses the damaged Ark being turned into a death trap. For refusing to relinquish access codes to Ackley, Bikrut declares Harrod "Raised" nearer to an Evolved status. However, Bikrut leaves Harrod stranded as he and other Evolveds separate from the Ark in its bridge, secretly refurbished to achieve orbit, and follow their Shaddock enemies onto the satellite.
- (11) Harrod is followed by helots to the auxiliary bridge, where he witnesses survivors of each House landing upon the mesa. Wondering about the fate of each House, Harrod steers the Ark toward the mesa in the trail of a swarm of helot-occupied escape pods.

Quiz/Reading Comprehension Questions:

1. What adjective best represents Harrod?
 - a. ambivalent
 - b. rebellious
 - c. neutral
 - d. loyal
2. What punishment would Harrod face if he obeyed a House Lord other than his own?
 - a. a whipping
 - b. death
 - c. public embarrassment
 - d. a lowering of military rank
3. Why are House Shaddock's Evolved so young?
 - a. They murdered and took the places of their Elders
 - b. House Shaddock believes that their young are blessed
 - c. Leaders of House Shaddock spent many days in cryogenic sleep
 - d. House Shaddock expected Exile and anticipated a long interstellar voyage
4. What is an example of a deceit Bikrut uses against Overlord Verone?
 - a. that he cherishes Harrod
 - b. that he behaves humbly toward Overlord Verone
 - c. that he intends not to go into Exile
 - d. that House Mellis is in possession of nuclear weapons

5. According to Harrod, instituting the Rite of Exile is analogous to:
 - a. committing murder
 - b. releasing pressure
 - c. obeying tradition
 - d. maintaining order
6. Bikrut's opinion that Harrod's refusal to give up access codes to House Shaddock is both "well done" and "stupid" is an example of:
 - a. irony
 - b. foreshadowing
 - c. paradox
 - d. antithesis
7. What is ironic about Ackley being Raised to sul-Shaddock?
8. According to Overlord Bikrut, what characteristic does Harrod lack in order to be Evolved?
9. What is the primary consequence to the people of Kalsor Tertius when their Great Ark is destroyed?
10. Why does Harrod want to land the Great Ark amidst a series of islands instead of upon the mesa?

Answers:

1. d
2. b
3. a
4. d
5. b
6. c
7. Ackley remains in the lowest position in a House of Evolveds.
8. Harrod lacks the instinct to dominate other humans, making him a "lesser being."
9. Without the Great Ark, the former colonists of Kalsor Tertius can no longer institute the Rite of Exile.
10. Harrod fears that upon the mesa environmental disasters might destroy his entire race, whereas divided among islands, his race may only be partially susceptible to disaster.

Critical Thinking Question:

1. Even when betrayed by Bikrut, Intendant Harrod remains loyal to him. Does true loyalty forgive unfair treatment? What does it mean to be truly loyal? Can loyalty for yourself outweigh loyalty to others?

Suggested Activity/Inquiry-Based Exploration: Harrod fears that his race is doomed to everlasting warfare due to a genetic flaw in its makeup. Have your students research recent discoveries in the science of genetics. Your students might write persuasive papers or organize a debate on whether genetics ultimately determines human fate, or whether humans can act against their “programming” to gradually influence their genetic makeup. Articles on genetic studies might be esoteric, but much information on how genes have been discovered to affect our lives may be found by simply searching “recently discovered genes” on Google.

FUSION STARSHIPS, Gregory Matloff

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - the root *thermo-*
 - foreshortened
 - contracted
 - meteoric
 - kinetic & potential energy
 - nuclear fission
 - censor
 - bombard
 - epochal
 - convene
 - conclave
 - plasma
 - ionized
 - reactant (*n.*)
 - bureaucracy
 - embittered
 - graphite
 - the root *kilo-*
 - ablative
 - the root *mega-*
 - deflect
 - copious
 - tenuous
 - micron
- Focus question/initiating activity: Investigate with your students the devastating effects of a nuclear bomb. Ask your students to consider that the technology used to create such a weapon may also provide humanity with incredible advantages. Footage of nuclear explosions may be found on the internet.

Essay Outline:

- ❖ Introduction main idea: Thermonuclear fusion reactors will be the basis for early interstellar travel.

Early Fusion History

- ❖ Main Idea: *Albert Einstein's discovery of mass-energy led to that of the "chain reaction," wherein enormous amounts of energy can be produced by splitting radioactive particles.*
- [165-66, ¶s 1-4] Imagining himself riding a beam of light, Albert Einstein conceived of Special Relativity, which states that the velocity of light remains constant regardless of the velocity of its source. In consequence, a moving source approaching the speed of light exhibits the Lorentz-Fitzgerald Contraction, which has three puzzling characteristics:
 1. The source appears to be shorter in length.
 2. The source's mass increases.
 3. Time within the source slows down.
- [166, ¶s 5-8] When Einstein conceived of time as a fourth dimension, he explained both the Lorentz-Fitzgerald Contraction and the connection between electric charges and

magnetism: a magnetic field is strengthened as a series of electric charges approach the speed of light and experience contraction, thus fitting more electric charges into a smaller space-time and creating a stronger electric field.

- [166-67, ¶s 8-9] Integrating gravity into relativity theory, Einstein also discovered that a gravitating object's mass literally bends the fourth dimension of space time, an effect known as General Relativity.
- [167, ¶s 10-11] In conceiving Special Relativity, Einstein also discovered that a stationary object upon Earth's surface has neither kinetic nor potential energy, but "rest-energy," which is found by multiplying the speed of light in vacuum by the mass of the object ($E=mc^2$). Consequently, objects are considered to have "mass-energy" because mass and energy can be converted into each other.
- [167, ¶s 12-13] Mass-energy conversion explains how decay particles in radioactive processes obtain their energy, and how stars can maintain stability for long periods of time.
- [167-68, ¶s 14-15] Einstein's mass-energy equation was utilized when German scientists bombarded a massive Uranium isotope with thermal neutrons, splitting the isotope into more nuclei and neutrons and producing an enormous amount of energy in a "chain reaction."
- [168-69, ¶s 16-21] Realizing the potential of the $E=mc^2$ formula to be used by Nazi Germany as atomic weaponry, Einstein wrote a warning letter to President Roosevelt, who gathered nuclear experts to verify Einstein's concerns.
- [169, ¶s 22-23] During the Cold War, the hydrogen bomb, more powerful than the original atomic bomb, was created by forming chain reactions through raising temperature, pressure, and density in light nuclear material.
- [169-70, ¶s 24-26] Contrary to building atomic weaponry, two types of electricity-producing fusion reactors have been proposed to solve Earth's energy needs:
 1. A confined-fusion reactor might use powerful electric and magnetic fields to confine plasma of thermonuclear material. Challenges with this type of reactor include:
 - a. Sustaining incredible temperatures and dealing with radioactivity
 - b. Achieving "technological breakeven," wherein the energy produced by a reactor is greater than its energy input
 2. [170, ¶s 27-28] An in-space inertial-fusion reactor might use electrons or laser beams to bombard pellets of fusion reactants, raising the pellets' temperatures to levels suitable for thermonuclear reactions to occur. An inertial-fusion reactor has a benefit over a confined-fusion reactor:
 - Whereas high-energy products of thermonuclear reactions would need to be shielded terrestrially, in-space electrically-charged particles could be redirected as space rocket exhaust.

Project Orion—Birth of the Interstellar Dream

- ❖ Main idea: *Starships might be propelled by utilizing the absorbed force of nuclear blasts.*
- [170-71, ¶s 1-3] When nuclear physicist Theodore Taylor placed a small steel sphere covered with graphite at ground zero of a nuclear explosion, he discovered that an object could survive such an explosion when covered with a shock-absorbing (ablative) material.
- [171, ¶s 4-5] In Project Orion, Taylor, along with other physicists, conceived that a spacecraft might be propelled by nuclear explosions that discharge behind a “pusher plate” coated with ablative materials. Furthermore, rocket speed would increase with each explosion.
- [171, ¶ 6] A test model using chemical explosives for propulsion was successfully employed, but a full scale Orion was never constructed.
- [171-72, ¶s 7-10] Although an Orion rocket, estimated to reach great velocities, was considered a candidate for lunar missions, an Atmospheric Test Ban stifled its popularity. Instead, the successfully-tested Saturn V rocket was nominated for lunar missions.
- [172, ¶s 11-14] Birthing the “Interstellar Movement,” nuclear physicist Freeman Dyson published a paper that used approximations of energy yields of thermonuclear explosives to demonstrate how gigantic “fusion pulse” ships could carry large populations to other star systems.

Projects Daedalus and Icarus—The British Interplanetary Society (BIS) follows Up

- ❖ Main idea: *Contrary to starships propelled by nuclear blasts, inertial fusion might be a more realistic technique in propelling smaller and more energy-stable starships.*
- [173, ¶s 1-2] BIS researchers Alan Bond and Anthony Martin recognized several problems with the Orion concept, including:
 1. An Orion starship would have to be huge in order to deflect nuclear blast particles
 2. Nearby nuclear blasts might psychologically affect crew members and passengers.
 3. It is unlikely world superpowers would be primarily interested in using nuclear technology in a constructive way.
- [173-74, ¶ 3] Contrary to the Orion rocket, the *Daedalus* utilizes inertial fusion, tamer than thermonuclear fusion as it combines less massive particles, preferably low mass Helium (He-3) and deuterium.
- [174, ¶s 4-5] Being rare on Earth, He-3 might be created with breeder reactors that demonstrate “technological breakeven,” electromagnetically scooped from ionic solar winds, mined from lunar soils, or, most preferable to starship designers, robotically-mined from the atmospheres of giant planets.

- [174-75, ¶s 6] Instead of a giant ship, *Daedalus* technology was conceived to be applied with high-velocity robotic probes that could travel to distant star systems.
- [175, ¶s 7-8] Following *Daedalus*, Project *Icarus* planned to improve on *Daedalus* concepts, targeting star Alpha/Proxima in the Centauri system, whose two stars are sun-like and separated enough to imply that planets may exist in stable orbits.
- [175, ¶s 9-10] *Icarus* researchers are planning non-rocket deceleration techniques to ensure ample time in which to gather data after a probe arrives at its destination star system. Possible approaches include:
 1. Reflecting interstellar plasma or stellar winds of the destination star(s)
 2. Directing a light sail toward the destination star(s) for complete deceleration.

The Fusion Ramjet

- ❖ Main idea: *An electromagnetic scoop may be used to gather particles with which to convert into spacecraft-propelling energy, but the force of thermonuclear reactions is still out of human control.*
- [175-76, ¶s 1-4] Envisioned by Robert Bussard as capable of approaching the speed of light, the interstellar ramjet leads a spacecraft to project an immense electromagnetic field that scoops up proton and electron “plasma” which is directed to the spacecraft’s fusion reactor. In the reactor, the plasma density and temperature increase sufficiently to fuse protons, producing helium and energy which is expelled through ship-propelling exhaust.
- [176-77, ¶s 5] In addition to requiring no on-board fuel, the ramjet can shield itself from near-light speed interstellar dust by its incoming proton flow colliding with and atomizing dust grains.
- [177, ¶s 6-7] Although intriguing to some science fiction authors, problems with the ramjet concept have been exposed, including:
 1. Electromagnetic scoops actually work to reflect interstellar particles, creating a braking effect.
 2. Technology does not yet exist that can control the powerful thermonuclear reactions required to propel a ramjet.
- [177, ¶s 8-9] Powerful thermonuclear reactions might be tamed by utilizing less massive particles gathered with larger electromagnetic scoops, but ramjets propelled by such reactions would be less efficient than Bussard’s original conception.

Quiz/Reading Comprehension Questions:

1. What concept of Albert Einstein's proposes that mass literally bends space-time?
 - a. special relativity
 - b. mass-energy
 - c. general relativity
 - d. rest energy
2. Nuclear fission can be described as:
 - a. Small radioactive nuclei combining to grow larger
 - b. The splitting of a radioactive nucleus into more nuclei and neutrons
 - c. A single radioactive nucleus growing after being combined with other particles
 - d. Heating radioactive particles until they explode violently
3. The concept of rest-energy shows that:
 - a. All mass stores both kinetic and potential energy
 - b. Energy increases with mass
 - c. An object regains mass as it expels energy
 - d. An object's energy decreases when it is at rest
4. What adjective best illustrates Einstein's feeling toward the "chain reaction" discovery?
 - a. ecstatic
 - b. disappointed
 - c. anxious
 - d. proud
5. How did a graphite coating protect a small steel sphere from a nuclear blast?
 - a. The coating evaporated, carrying off energy from the explosion
 - b. The coating remained around the ball as it could stand extreme temperatures
 - c. Graphite insulated the sphere, maintaining a non-destructive temperature
 - d. None of the above
6. Repeated nuclear explosions behind an Orion rocket ensure:
 - a. A constant velocity
 - b. A build-up of potential energy
 - c. A decrease of potential energy
 - d. An increase in velocity
7. Explain one challenge with ramjet technology.
8. What is a limitation in accelerating and decelerating fusion rockets?
9. In Jack McDevitt's "Lucy," how does Sara decelerate her fusion starship *Excelsior*?
10. What kind of "breakeven" in the development of fusion reactors is most desirable? Why?

Answers:

1. c
2. b
3. b
4. c
5. a
6. d
7. Possible answers: Electromagnetic scoops might cause a braking effect; we do not have the technology to control powerful thermonuclear reactions.
8. Accelerating and decelerating fusion rockets requires enormous amounts of fuel.
9. Lucy swings the ship around, using the force from the engines to brake the ship.
10. "Technological breakeven" is most desirable because it ensures that the amount of energy produced by a fusion reactor is at least ten times greater than the energy input.

Suggested Activity/Inquiry-Based Investigation: Matloff addresses Einstein's valid concerns about the destructive uses of the chain reaction. In small groups, have your students research technological discoveries or developments that could be used both constructively and destructively. Examples of such technologies might be atmosphere-manipulation devices, or even the internet. Allow each group to present a graphic illustration to exhibit possibilities for each technology. You may also have your students develop their data into pro/con papers. Some useful resources:

- Information on the High Frequency Active Auroral Research Program (HAARP) can be found at <http://www.haarp.alaska.edu/haarp/index.html>. HAARP manipulates portions of the ionosphere to influence weather systems.
- A thorough webpage on Anonymous, a group of computer hackers that work in the name of civil disobedience, can be found at Wikipedia. [http://en.wikipedia.org/wiki/Anonymous_\(group\)](http://en.wikipedia.org/wiki/Anonymous_(group)).
- An article about recent scientific uses of military satellites can be found at Popular Mechanics. http://www.popularmechanics.com/science/space/4326977?click=main_sr.
- An article on a Russian "guard dog" robot, programmed for surveillance, may be found at the Tecca website <http://www.tecca.com/news/2011/04/17/tral-patrol-3-robot/>.

***PROJECT ICARUS—A THEORETICAL DESIGN STUDY FOR AN INTERSTELLAR SPACECRAFT*, Dr. Richard Obousy**

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - exoplanet
 - tantalizing
 - feasibility
 - extrapolation
 - superluminal
 - the prefix *sub-*
 - Jovian
 - nanotechnology
 - analogous
 - threshold
 - codify
 - precursor
 - luminaries
 - synonymous
 - relativistic electron beam
 - liberate
 - salient
 - treatise
 - audacity
 - extrapolation
 - prototype
- Focus question/initiating activity: Ask your students if they have ever seen images of the universe beyond our Milky Way Galaxy, and if so, if they remember the first time they saw such an image. Search NASA’s “Astronomy Picture of the Day” archive (<http://apod.nasa.gov/apod/archivepix.html>) for a variety of images gathered by satellites and telescopes. In a quick-write, have your students respond to the question, “Why might it be important to explore the universe?”

Essay Outline:

Motivations for Project Icarus

- ❖ Main idea: *New technology and knowledge has rebirthed projects aimed at making interstellar travel a reality.*
- [180, ¶s 1-2] A recent estimation of an enormous number of exoplanets in habitable zones is countered by the Fermi Paradox, which weighs the likelihood of alien life against a contradictory lack of evidence for it.
- [180-81, ¶ 3-4] While one solution to the Fermi Paradox is the theory that interstellar travel is not possible in regards to its timescale, sublight interstellar travel is still considered theoretically possible.
- [181, ¶s 5-6] Though the British Interplanetary Society (BIS) determined that a *Daedalus* spacecraft is presently unfeasible due to its necessary mass coupled with the difficulty in acquiring Jovian He-3, the *Daedalus* and *Icarus* projects have been reassessed in the wake of new technologies and cosmic knowledge.

Origins and Birth of *Project Icarus*

- ❖ Main idea: *Icarus* originated to reassess *Daedalus*.
- [181-82, ¶s 1-3] Originating in 2008 out of discussions concerning a *Daedalus* redesign, *Project Icarus* reassessed fundamental assumptions concerning the function of a *Daedalus* spacecraft. Since then, *Icarus* has gained public visibility, as well as volunteer designers and consultants.

Icarus: A Lesson in Mythology

- ❖ Main idea: *Icarus*' mission is to improve upon *Daedalus*.
- [182, ¶ 1-2] (*Icarus* myth summarized); *Icarus* is intended to improve upon methods conceived in *Project Daedalus*.
- [182-83, ¶s 3] Contrary to the regular interpretation of mythological *Icarus*, an alternative suggests that *Icarus* merely illuminated structural flaws in the flying machines of his era.

Purpose and Ambitions of *Project Icarus*

- ❖ Main idea: *Project Icarus* intends to build an inspiringly advanced spacecraft that can reach and measure a target solar system with revolutionary precision.
- [183-84, ¶ 1-3] As well as to inspire more interest in interstellar travel, *Project Icarus*'s purposes include the following expectations:
 1. An unmanned probe must be capable of accurately measuring characteristics of a target solar system.
 2. Measured against the original *Daedalus* design, the spacecraft must be technologically current/near-future and launched ASAP.
 3. The star target must be reached in reasonable time.
 4. The spacecraft must be able to visit a variety of target stars.
 5. The spacecraft propulsion must be fusion-based.
 6. The spacecraft must be able to decelerate enough to ensure increased encounter time with the target star (with a cruise velocity 12% of light speed, *Daedalus* would have only seconds to encounter a planet and a minimum of days to traverse a solar system).

Parallel Objectives

- ❖ Main idea: *Project Icarus* intends not only to improve upon *Daedalus*, but to definitively advance human technology.
- [184-85, ¶s 1-3] Additional motives behind *Project Icarus*:

1. To create a vehicle for training a new generation of interstellar engineers by project completion
 2. To make interstellar flight a practical endeavor
- [185, ¶s 4-5] Two reasons why *Daedalus* was impractical:
 1. Inertial Confinement Fusion (ICF) requires many consecutive events of igniting deuterium/He-3 pellets with electron beams in a reaction chamber; however, currently only one pellet ignition can be performed in a day's time.
 2. Helium-3, *Daedalus*' main fuel, is incredibly rare on Earth and would be difficult to mine from Jupiter's atmosphere without an expensive space-based infrastructure in place.
 - [185-86, ¶s 6-9] Another motive behind *Project Icarus* is to set realistic engineering designs by improving Technology Readiness Levels (TRLs). These levels are based on a scale that ranges from observations on the low end to full applications on the high end.
 - [186, ¶ 10] *Project Icarus* intends to achieve Readiness Levels that exceed *Daedalus*' maximum levels of TRL 3.
 - [186-87, ¶ 11] A final motive of *Icarus* is to measure the efficacy of a virtual environment of volunteer researchers, aiming ultimately to create a prototype for future scientific and engineering endeavors.

Nuclear Fusion—A Propulsion Scheme for the Future

- ❖ Main idea: *Thermonuclear fusion is currently the most viable way to produce enormous amounts of energy.*
- [187, ¶ 1] *Project Icarus* is based on fusion propulsion, a system to which there is no current alternative.
- [187, ¶ 2] In fusion, kinetic energy and electromagnetic radiation is formed when two atoms are kinetically energized to merge and create a larger atom.
- [187-88, ¶s 3-4] Fusion processes are radically more efficient than chemical processes, but machines do not yet exist that can harness fusion energy. Contrarily, fusion energy has only been successfully utilized in rapid and uncontrollable thermonuclear explosions.
- [188, ¶ 5] ICF is promising because charged reaction products themselves are utilized as thrust via magnetic nozzles, leading to fewer thermodynamic losses.
- [188, ¶ 6] Though many approaches to nuclear fusion have been considered, an ideal approach has yet to be realized.

Quiz/Reading Comprehension Questions:

1. According to the Fermi Paradox, what contradicts high estimates of extraterrestrial civilizations?
2. What is new about Sir Arthur Eddington's interpretation of the mythological Icarus?

3. Why is deceleration a major concern for an interstellar probe mission?
4. Considering that a fusion-based propulsion system falls only at 2 on the Technology Readiness Level scale, it seems as though humans have a long road ahead of them in terms of developing technologies for successful interstellar travel. Based on a previous essay in this anthology, what other “scale” does human civilization fall low on, and what does our placement on this scale express about humanity?
5. What is primarily unique about the *Project Icarus* research team?

Answers:

1. A lack of evidence for such civilizations.
2. Icarus did not fail in flight, but rather illuminated deficiencies in the flying-machines of his era.
3. In order for a probe mission to be considered successful, the probe must decelerate enough so as to have adequate time to survey a planet and its solar system.
4. The Kardashev scale puts humanity below a Tier 1 civilization, defined by being able to harness all of the sun’s energy absorbed by Earth.
5. The team collaborates almost completely via the internet, with only some communication via internet telephony.

Critical Thinking Question:

1. Though the Kardashev scale provides a rational framework for envisioning the future of humanity, imagine the possibility that Earth humans might never breach the confines of the Milky Way Galaxy. If we knew that Earth would be our primary home for the remaining lifespan of our civilization, by what tiers might we measure our success as a species?

Creative Writing Assignment: Have your students read the “Daedalus and Icarus” myth. This myth can be found in Ovid collections, in Edith Hamilton’s *Mythology*, and as a reworking by Anne Terry White. After reading, ask your students to rewrite the myth in either a contemporary or future setting; suggest that an outer space setting is welcome. Students may also illustrate key moments in their myths by hand or on computer.

DESIGN FLAW, Louise Marley

Major Characters:

- ISABET (“Itty Bit”) is a maintenance tube technician aboard the starship *North America*.
- MR. DYKENS (“Tye Dye”) is an abusive engineer aboard *North America*.
- LINK is the store manager of *Starhold*’s loading bay on Jupiter’s moon Ganymede.
- GINGER, SKUNK, and HAPPY are antimatter containment ring technicians aboard *North America*.

Prepare to read:

- Familiarize yourself with the following vocabulary and terms:
 - Ganymede
 - superfluous
 - protocol
 - differential
 - flux
 - phlegmy
 - stature
 - agility
 - g-ray
 - positronic reactor
 - redress
 - aft
 - indignities
 - myriad
 - ovoid
 - hydroponic
 - momentum
 - insignia
 - exasperated
 - constellation
 - asbestos
 - mollify
 - reconstituted
 - inverted
 - suffused
 - infinitesimal
 - accentuate
 - interminable
 - cessation
 - impotent
- Focus question/initiating activity: Investigate with your students amendments to the United States Constitution, which may be found at the National Archives website http://www.archives.gov/exhibits/charters/constitution_amendments_11-27.html. Draw emphasis on the amount of time it took for women to gain the right to vote.
 - Ask your students to consider what stereotypes about women continue to contribute to disadvantages they might experience in the current day. Reinforce the idea that these disadvantages might not always be tangible, but rather exist in the realm of ideas.

Plot Summary:

- [pgs. 191-94] In orbit of Jupiter moon Ganymede aboard the starship *North America*, ring tech Isabet checks the stability of the ship's antimatter containment ring. Upon returning from her check, Isabet is intentionally touched upon her chest by Tye Dye, an engineer.
- [194-97] With fellow ring techs Happy, Ginger, and Skunk, Isabet weighs the undesirable conditions aboard *North America* against those on Earth. Isabet deftly notices that *North America* is braking and will achieve its target within three days.
- [197-201] Gathered in an aft observation area, Isabet and her fellow techs await arrival at *Starhold One*, a habitat on Ganymede. Isabet explains to Ginger the goal of mining sufficient antimatter from Ganymede to propel an interstellar starship. Entranced by the sight of *Starhold One*, Isabet expresses hope that she may partake in an interstellar voyage.
- [201-03] In an Engineering quarter of *North America*, a female supply officer reassigns an eager Isabet to the Supply Deck.
- [203-19] In the loading bay of *Starhold*, Isabet considers the ineloquent construction of the sealing ring connecting to *North America*. Isabet meets Link, who explains how the sealing ring works and is maintained, focusing particularly on a "crawler" robot inside the ring, designed to find pressure leaks, and whose legs are dangerously sharp due to a design flaw. Isabet considers Tye Dye's abuse, whose unwanted sexual advances she had once turned down. Isabet enjoys her time with Link as they share work experience. Link offers Isabet a tour of *Starhold*, which Tye Dye does not allow. After being dragged away from Link, Isabet tries to reason with Tye Dye, but Tye Dye attempts to rape her. Isabet escapes Tye Dye's hold, climbs to the threshold of the sealing ring, and edges inside, dodging the crawler. Tye Dye, however, sends the crawler after Isabet, forcing Isabet to crawl further along through the ring. Isabet realizes not only that the ring is leaking pressure, but that Tye Dye has locked her inside the ring. Isabet finds the ring's instrument panel and sets off a leak alarm, deactivates the crawler, and requests that *Starhold* separate from *North America* for the leak. Link helps Isabet out of the ring and onto her feet, offering her a home at *Starhold*. Link and Isabet watch as *North America*, with Tye Dye, sets sail back to Earth.

Quiz/Reading Comprehension Questions:

1. Isabet considers that even if an antimatter containment ring is positioned only a fraction of a centimeter off, it may result in a dangerous leak. What adjective best expresses this condition?
 - a. unpredictable
 - b. trivial
 - c. precarious
 - d. volatile

2. What is a common characteristic between Isabet and her fellow ring techs?
 - a. They all want to participate in interstellar voyages
 - b. They all experienced poverty on Earth.
 - c. They all want to work at *Starhold*.
 - d. They all are small due to malnourishment.
3. What are humans doing on Ganymede?
 - a. building an antimatter plant
 - b. mining extraterrestrial artifacts
 - c. setting up a gigantic satellite
 - d. building a starship
4. Why does Skunk argue that he and his fellow ring techs will not live long enough to witness interstellar travel?
 - a. They are small and unfit for interstellar travel
 - b. They will probably die on Earth, which has become a violent place
 - c. Ship design will eventually improve so that ring techs are no longer needed
 - d. They are being exposed to more gamma rays than other people
5. All of the following adjectives describe the only female that Isabet meets at *Starhold* except:
 - a. composed
 - b. unemotional
 - c. nonchalant
 - d. stoic
6. On what does Isabet blame for her disinterest in intimate relations with other people?
 - a. her experiences in shelters on Earth
 - b. her vulnerable size
 - c. her abuse from Tye Dye
 - d. her obsessive focus on her job
7. What is contradictory about Isabet's description of Ganymede and *Starhold*?
8. What does Isabet compare to crawling through the sealing ring?
9. Why does Isabet enjoy working inside maintenance tubes?
10. Recall Matloff's essay on fusion starships. How was Freeman Dyson's experience with his government similar to Isabet's experience with *North America's* command?

Answers:

1. c
2. b
3. a
4. d
5. c
6. a
7. She describes Ganymede as “massive” and “delicate” and *Starhold* as “massive and graceful.”
8. Isabet compares crawling through the sealing ring with having to choose between evils at shelters.
9. Isabet feels safe inside the tubes because no one can bother or harm her.
10. Both Dyson and Isabet felt that their concerns for other peoples’ or their own safety were not being taken seriously.

Critical Thinking Questions:

1. Marley exhibits how common flaws in human nature, such as male chauvinism, might remain an issue well into humanity’s future. Assuming that improvements in human nature do not necessarily follow from technological advancement, what other natural flaws might accompany humanity as we venture into outer space?
2. Even though Marley presents a civilization whose technological capabilities presently far exceed our own, travelling between Earth and Ganymede still takes long intervals of time. What other limitations might accompany humanity into an era of interstellar travel?

Suggested Activity/Inquiry-Based Exploration: Remind your students that even though “Design Flaw” takes place in the considerable future, Isabet and her crewmates imply that such hardships as poverty, starvation, and discrimination still exist on Earth. Divide your students into small groups and ask them to brainstorm what societal faults or limitations might follow humans into outer space. Ask each group to make a list of disorders in their own society, such as homelessness, crime, drug abuse, violence, mental illness, etc. Allow each group to voice several of its ideas, allowing your class to come to a consensus on a top five or ten list. After coming to a consensus, ask your students to write a short reflection on discoveries or realizations they may have had during the activity.

TWENTY LIGHTS TO ‘THE LAND OF SNOW’: EXCERPTS FROM THE COMPUTER LOGS OF OUR RELUCTANT DALAI LAMA, Michael Bishop

Major Characters:

- GRETA BRYN BRASSWELL/GYATSO is the reincarnated Dalai Lama, though she has her doubts.
- NYENDAK “NEDDY” TRUNGPA is a Tibetan minister, and was a friend of the late Dalai Lama, Sakya Gyatso.
- LAWRENCE “LARRY” RINPOCHE is Greta’s tutor. He is also a former movie star.
- IAN KILKHOR is Greta’s bodyguard and stand-in tutor.
- CAPTAIN XAO SONGDA is the aging commander of *Kalachakra*.
- NIMA PHOTRANG is the first officer of *Kalachakra*.
- TECH BRASSWELL (SIMON BRYN) is Greta’s father. He believes Greta should consider her own happiness before that of others.
- TECH BONFILS (KAREN BRYN) is Greta’s mother. She believes in Greta’s destiny as The Dalai Lama.
- JETSUN TRIMON is a candidate to be The Dalai Lama.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms...
 - chakra
 - the root *somni-*
 - horticulture
 - the root *urs-* / Cf. *ursa*
 - the root *dorm-*
 - loco (*Sp.*)
 - fuddle
 - the suffix *-ize*
 - the prefix *hypno-*
 - the root *spect-*
 - pragmatism
 - klutz
 - Bhodisattva
 - ginormous
 - unorthodox
 - bardo
 - burro
 - dodgy
 - pipedream
 - mirage
 - the prefix *holo-*
 - terminator (of a planet)
 - quantifiable
 - mandala
 - console
 - jettison
 - adjacent
 - crone
 - intranet
 - gompa
 - chörten (stupa)
 - agnostic
 - agate
 - protégée
 - subsidiary
 - regent
 - tai chi chuan
 - disenfranchise

- Panchen
- autocrat
- the prefix *ante-*
- iconography
- somatic
- stodgy
- elixir
- turbid
- catechism
- apostate
- benighted
- ensorcelled
- surrogate
- forfeit
- synopsise
- the Cf. *crypto-*
- samsara
- nirvana
- presage
- sutra
- Lhündrub Tögal
- codicil
- namasté
- pedagogy
- subterfuge
- temporal
- mausoleum
- Byronic hero
- seraph
- gravid
- gnosis
- connate
- inchoate
- koan
- oblate
- albumin

- Focus question/initiating activity:

1. While listening to the first movement of Henryk Górecki's "Symphony of Sorrowful Songs", investigate with your students religious images of Tibetan Buddhism, including mandalas, the namasté gesture, Bhodisattva and nirvana depictions, Buddhist monks and nuns, and Buddhist monasteries. Next, highlight Tibet on a world map, and display modern images of Tibetan protests. Inform your students that the Tibetans have been fighting for independence from China, which desires to control Tibet for historical, agricultural, military, and political reasons. Explain that Tibet's fight for independence has resulted in the exile and death of many Tibetans. Ask your students why Bishop might have included Górecki's Third Symphony in his story.
2. Have your students investigate the cross section of *Kalachakra* at the end of Bishop's story. Consider displaying images of other strut or truss structures, emphasizing that these structures are basically architectural skeletons. Remember with your students essays from *Going Interstellar* that stressed the need for a starship to be lightweight.

Plot Summary:

- [pgs. 221-25] Aboard the strut-ship *Kalachakra*, headed in its eighty-second year to Gliese 581's planet Guge (Gliese 581 g), seven-year-old Greta Bryn Brasswell is awoken during an "up-phase" from hibernation in her habitat drum named Amdo Bay. Accompanied psychically by her "ghost" parents, Simon and Karen Bryn, Greta is monitored for comprehension of her surroundings by Minister Nyendak Trungpa, who expresses his belief that Greta is a reincarnation of the former Dalai Lama, Sakya Gyatso. Greta is distraught at the notion that "I'm not I," and that she will be separated from her parents.
- [225-28] Though fearful of her possible role as Dalai Lama, Greta is relieved to be allowed to stay in up-phase, out of hibernation. Greta converses with her tutor, Larry, about the possibility that she is the reincarnated Dalai Lama, and the conundrum of her soul's location, considering that she was born before Sakya Gyatso died, or according to Larry, was murdered. Greta spends her time in up-phase learning about *Kalachakra*, psychically travelling about the ship as a ghost, occasionally conversing with other ghosts.
- [228-31] As a ghost in up-phase, Greta feels vulnerable travelling about *Kalachakra* as she considers Sakya Gyatso's possible fate, and also as she comes upon the ghost of a mysterious snow leopard. From educational devices Greta learns the population of the *UNS Kalachakra*, and that they are exiles; the distance of *Kalachakra* from Gliese 581; the location of each sleep Bay and the types of people assigned to them; the conditions of Bay sleep; the characteristics of Gliese 581 and of Guge, whose snowy habitable zone lies between a scorching sun- and freezing dark-side; when Guge was discovered; and that Sakya Gyatso rarely hibernated, but did so in an extreme sleep. Greta worries over Sakya Gyatso's death.
- [231-36] A year older, Greta remains in ghost form for safety while her parents hibernate. Greta visits First Officer Nima Photrang, who informs Greta that the remaining trip to Guge will take over twenty years including braking. Photrang expresses her doubts that Sakya Gyatso was murdered, or even had a heart attack, but rather committed suicide by avoiding age-preserving hibernation in order to maintain his leadership role upon *Kalachakra*; Greta is offended by this notion and leaves Photrang. In her Bay room, Greta is visited by Captain Xao, who inquires about her doubts concerning the death of Sakya Gyatso. After Greta expresses a multitude of doubts concerning her identity and the *Kalachakra* voyage, Captain Xao indirectly admits that he believes Sakya Gyatso was murdered.
- [239-44] At age twelve, the notion that Greta is the reincarnated Lama is increasingly embraced throughout *Kalachakra*, realized in an invitation for Greta to visit her childhood nursery to play with children and be offered sacred gifts on her birthday. Greta is enchanted by a baby. Months later, Greta shares a meal with her parents in physical state, and her father informs her that he and Karen are divorcing. Momentarily numb to

the news, Greta expresses the uncertainty of her Lamahood and criticizes Minister Trungpa, for which she is scorned by Karen.

- [244-46] Nearly thirteen, Greta suspects that an investigation into the death of Sakya Gyatso has been intentionally diverted; Greta, however, is assigned a bodyguard, Ian Kilkhor, who tutors Greta while Larry spends time hibernating. Kilkhor also acts as a representative for Greta to other religious figures aboard *Kalachakra*. Greta fears that her birth date will not only invalidate the notion that she is the reincarnated Lama, but that she will be assassinated.
- [246-51] During her fourteenth year, the integrity of Greta's Lamahood is tested by a group of monks and a nun, including *Kalachakra*'s high-ranking Panchen Lama, who ask Greta to choose out of a variety of items those which were owned by Sakya Gyatso. Greta uses memory and logic to correctly choose a cloak and a book cherished by Sakya Gyatso. Guided by the indicative behavior of Sakya Gyatso's monkey, Chenrezig, Greta correctly chooses several more items. A leading monk, however, remaining doubtful, demands a miracle from Greta. Suddenly, Chenrezig approaches and embraces Greta, convincing all but the leading monk of her Lamahood.
- [251-55] Four years later, Greta takes part in catechisms led by Larry, Kilkhor, and Captain Xao in which she reiterates by rote beliefs, motivations, and a history of the oppression of the Tibetan people. Greta expounds not only on how this oppression led to a Tibetan Earth-exile which necessitated the building of a multigenerational starship, but also on the reasons for China's acquiescing to the venture. The catechism concludes with a vision of fulfilling the goal of establishing a Guge colony which may be a place of spiritual enlightenment for present and future generations.
- [255-59] At age nineteen, Greta is informed that another child, Jetsun Trimon, is being considered as the possible reincarnation of Sakya Gyatso. Confounded and annoyed, Greta decides to hibernate for a significant part of a year. Upon waking, Greta is joined by Karen, Minister Trungpa, the Panchen Lama, Kilkhor, and Jetsun. It is revealed that Greta and Jetsun's Lamahood will be decided by lottery in a drawing from a gold urn at *Kalachakra*'s Jokhang Temple in U-Tsang bay, where Sakya Gyatso's body will be on display.
- [260-66] Six months later, Greta is accompanied by family and instructors to Jokhang Temple in a gravity-less journey. After ambivalently following a guiding snow leopard ghost into a tunnel, Greta and her company partially fall with an increase in gravity into the Temple courtyard at U-Tsang. Greta and her companions are greeted by monks and other Tibetans, including the Panchen Lama, at the Temple. With Karen and Larry, Greta observes the body of Sakya Gyatso and reflects upon his spiritual accomplishments and public persona. Overcome by feelings of awe and inadequacy, Greta cries uncontrollably, expressing her disbelief in her Lamahood, while Karen, though momentarily supportive, faints in despair.

- [266-74] Awake from her faint, Karen explains that her faint was caused by Greta's refusal to partake in the Gold Urn Lottery, along with the image of Sakya Gyatso's face. Karen reasserts her belief that Greta is the reincarnated Dalai Lama with a story involving her ongoing affair with Minister Trungpa, which began during her marriage to Greta's father. (Upon discovering the affair, Sakya Gyatso fell into a spiritual confusion and lethargy. To reinvigorate Gyatso, Trungpa brought Gyatso to a *Kalachakra* nursery, where he became obsessed with Greta and later expressed his desire that she resume his leadership aboard *Kalachakra* and in "The Land of Snow." After much consideration, Karen expressed her wish that Greta's soul be infused with that of Gyatso. When this wish was communicated to Gyatso, Gyatso committed himself to die and occupy Greta.) Greta hears Karen's story regretfully.
- [274-78] At a lounge, Greta meets with her father, Simon, who openly admits his awareness of his wife's affair, and asks Greta whether she believes that she is the reincarnated Dalai Lama. Simon also admits that he joined the *Kalachakra* journey not for religious belief, but love for Karen and an interest in spaceflight. Greta expresses ambivalence to the notion of being a Dalai Lama, simultaneously noticing the attention being paid her and her father. Greta greets an old acquaintance, whose mother wishes Greta good luck at the Gold Urn Lottery. Greta also remembers, to her father's doubt, once caring for her acquaintance like a mother.
- [278-80] Greta arrives the following day at Jokhang Temple to a throng of witnesses. After considering the dilemma of assuming an involuntary identity, Greta floats toward a dais with Jetsun where the Gold Urn resides. The Panchen Lama announces that a name will not be drawn from the urn, but will rise willingly. After nearly an hour, an envelope rises out of the urn.
- [281] A year has passed. While Greta's and Jetsun's parents are raised to nobility, and Jetsun declares his own path to spiritual enlightenment, Greta rotates living spaces within *Kalachakra* to maintain peace among its inhabitants as the new Dalai Lama.
- [281-84] At age twenty-four, Greta considers the seven remaining years it will take to reach Guge. To Minister Trungpa Greta expresses her desire for *Kalachakra* inhabitants to compete in designing a sand mandala which will commemorate their journey's approaching end. Though Trungpa criticizes the competition for diminishing a sense of community among *Kalachakra*'s Tibetans, Greta argues that such a competition will provide much needed entertainment. Greta then informs Trungpa that she would like to have a baby, requesting his advice on whether to choose Kilkhor or Jetsun. Trungpa emphasizes many of Kilkhor's attributes, while shunning Jetsun for his young age.
- [284-86] Greta invites Jetsun to her quarters, where they simultaneously realize their desire for each other. Before consummating, Greta expresses her desire for Jetsun to impregnate her. Jetsun accedes to this desire, and also consents to the rearing of their child both aboard and off-board *Kalachakra*. Suddenly without gravity, Greta and Jetsun float to one another to consummate. Greta is certain that she has conceived with Jetsun.

- [286-89] A year later, Greta reflects upon *Kalachakra*'s early tradition of monks creating and erasing a yearly sand mandala, until a malfunction in the ship's artificial gravity caused damage to an unfinished design. Greta is visited by First Officer Photrang, who informs Greta that among many of *Kalachakra*'s inhabitants, Captain Xao is designing a sand mandala. Greta allows Photrang to touch her pregnant belly.
- [289-93] Greta delivers her baby, Kyipa, in the presence of family and friends. Kanjur Paljor, *Kalachakra*'s fuel specialist, regrettably approaches Greta to inform her that for over a hundred hours *Kalachakra* has been travelling at top speed at an angle slightly off its original trajectory, which might cause *Kalachakra* to prematurely run out of fuel. Paljor further explains that this unintended divergence was caused by inattention from an aging and stressed Captain Xao, at once obsessed with creating a sand mandala.
- [293-95] Against the opinion of many that believe a Dalai Lama should not have a child, Greta cherishes Kyipa as a legacy and a source of enlightenment. In the meantime, Greta worries about the fate of *Kalachakra*, which has already used its fuel reserves, but must use more fuel in order to brake. Greta communicates *Kalachakra*'s challenges openly to its inhabitants, who work together to strategize fuel conservation.
- [295-97] In Greta's twenty-seventh year, Captain Xao dies in a maniacal state, partly exhibited in numerous irrational mandala sketches and computer designs. Captain Xao is forgiven for his navigational error, and Greta decides to lay him to rest on Guge.
- [297-98] Four years away from Guge, newly-appointed Captain Photrang assures Greta that, barring any disaster, *Kalachakra* should reach its destination. Greta and Jetsun decide to keep Kyipa up-phase for the remainder of the trip, ensuring that she learns and grows before reaching Guge.
- [298] Less than a week away from arriving at Guge, *Kalachakra* is preoccupied with maintenance and prayer.
- [298-99] *Kalachakra* obtains Guge orbit, and Greta is presented a sand mandala, whose image is transmitted across the ship. Greta refuses to ritualistically destroy the mandala until *Kalachakra*'s colony has established itself on Guge.
- [300-01] Greta and her colonists settle upon "The Land of Snow" in a basecamp and region decidedly named "Lhasa" and "New Tibet." Trungpa presents Greta with a photo of Sakya Gyatso as a child holding his baby sister, who died as an infant.

Quiz/Reading Comprehension Questions:

1. What is the best indicator of Greta's age during the beginning of her journey?
 - a. Greta's sickness upon waking from ursidormizine hibernation.
 - b. Greta's playfully developmental language
 - c. Greta's memory of the Dalai Lama
 - d. Greta's doubt that she is the reincarnated Dalai Lama

2. What image does Larry use to explain to Greta a soul's reincarnation?
 - a. one candle lighting another
 - b. one candle trading places with another
 - c. one soul swimming into another soul
 - d. one fish swimming from its tank to another tank
3. Captain Xiao's expression that "We'll need every hand on the ground once we're all down on Guge" is an example of:
 - a. hyperbole
 - b. pun
 - c. metonymy
 - d. personification
4. Why must Guge be settled on its terminator?
 - a. The terminator maintains habitable temperatures.
 - b. The terminator most closely resembles Old Tibet.
 - c. The terminator region harbors Guge's most breathable atmosphere.
 - d. The *Kalachakra*'s trajectory ensures arrival directly at Guge's terminator.
5. What technology on *Kalachakra* functions unpredictably?
 - a. inducing ursidormizine slumber
 - b. shedding spent fuel tanks from *Kalachakra*
 - c. bringing ursidormizine hibernators up-phase
 - d. maintaining artificial gravity
6. What serves as a "miracle" supporting the belief that Greta is the reincarnated Dalai Lama?
 - a. Greta correctly chooses items that once belonged to Sakya Gyatso.
 - b. Sakya Gyatso's monkey approaches Greta and embraces her.
 - c. Greta remembers being visited by Sakya Gyatso when she was four.
 - d. Sakya Gyatso's monkey gives clues to Greta as she chooses Gyatso's belongings.
7. All are reasons that China supported the Tibetans in building a starship *except*:
 - a. China wanted to be the first nation to build a multigenerational starship.
 - b. China wanted to rid itself of the presence of the 21st Dalai Lama.
 - c. Exiling the Tibetan people by starship was seen as a more tolerable form of "ethnic cleansing".
 - d. Chinese manufacturing industry boomed as it contributed to the starship's construction.
8. When Greta refers to her almost year-long hibernation as a "nap," it is an example of:
 - a. hyperbole
 - b. understatement
 - c. sarcasm
 - d. irony

9. According to Greta's father, Simon, Buddhists aspire to:
 - a. material happiness
 - b. endless reincarnation
 - c. detachment from material things
 - d. understanding the meaning of life
10. What pair of adjectives best describes the tone in which "The Land of Snow" ends?
 - a. lighthearted and optimistic
 - b. foreboding and ominous
 - c. despairing and anxious
 - d. bittersweet and hopeful
11. Explain how Greta shows her Western influence when she asks her fellow Tibetans to submit sand mandala designs.
12. According to Greta, when did the tradition of creating and destroying sand mandalas come to an end on *Kalachakra*?
13. What purpose for Greta will laying Captain Xao's body upon planet Guge serve?
14. What is symbolized by the destruction of a sand mandala?
15. What gift does Minister Trungpa give Greta?

Answers:

1. b
2. a
3. c
4. a
5. d
6. b
7. a
8. b
9. c
10. d
11. Greta promotes competition between Tibetans, which contradicts the mandala's symbolic message of community.
12. A sand mandala was prematurely destroyed when *Kalachakra*'s artificial gravity momentarily shut down.
13. Captain Xao will represent the Tibetan's first sacrificial alms to planet Guge.
14. The destruction of a sand mandala symbolizes the impermanence of life.
15. Minister Trungpa gives Greta a photo of Sakya Gyatso as a young boy holding his infant sister.

Critical Thinking Questions:

1. Bishop illustrates a culture in which souls are believed to transfer between bodies in order to maintain an undisputed line of enlightened leadership. Consider what Bishop's story reveals about how *your* society establishes its leaders? In what ways do we put our "souls" into our leaders, or candidates?
2. When as a young child Greta wonders whether or not her parents liked each other, she refers to Stephen Hawking's quote that "People are not quantifiable," which was Hawking's response to the question of how he compared to Albert Einstein. How does Hawking's idea disagree with the notion that The Dalai Lama repeatedly reincarnates?

Summary Activity/Inquiry-based Exploration: In a quick-write, ask your students whether or not they wanted Greta to become The Dalai Lama, and have them justify their answers in discussion. Display the terms *predestination*, *divine election*, *religious rebirth*, and *bloodline*. Tell your students that they will be researching cultures around the world that believe that leaders are involuntarily assigned their power. Divide your students into small groups and have them each research a single culture whose leader came into or sustained power through ideas and beliefs represented in the aforementioned terms. On chart paper or posterboard, ask each group to write a brief summary about their chosen leader/line of leaders, along with a T-Chart that exhibits both positive and negative attributes of their chosen leader/line of leaders. Allow for brief discussion after each presentation.

SOLAR AND BEAMED ENERGY SAILS, Les Johnson

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - deployed
 - magnitude
 - proportional
 - inversely
 - rendezvous
 - near-term
 - subsystem
 - fabrication
 - commensurately
- Focus question/initiating activity: Investigate with your students the power of solar pressure at the Naval Research Laboratory website <http://sungrazer.nrl.navy.mil/>. You may also watch Comet Lovejoy's tail being whipped by solar winds at the science website Scoop <http://www.scoop.it/t/science-news/p/829888299/it-s-a-windy-day-in-space-for-comet-lovejoy>.

Essay Outline:

- ❖ Main idea (¶s 1-6): *Solar sailing might provide an energy-efficient method of interstellar travel.*
- [304, ¶s 1- 3] As an ocean ship is propelled by a momentum (the sum of mass time velocity) created by winds reflected off a sail, so might an in-space ship be propelled by solar pressure (sunlight), which acts like wind as it pushes through space.
- [304, ¶ 4] Photons, or particles of light, have been discovered to have no mass, even though they have momentum.
- [304-05, ¶ 5-6] While a modern shuttle can produce great thrust for a short period of time, a very large solar sail might provide continual thrust, however small, as long as it remains in the “fuel” of sunlight. Meanwhile, a chemical rocket would still be needed to propel a shuttle into Earth orbit.
- ❖ Main idea (¶s 7-10): *The closer to the sun that a solar-sailed spacecraft can be flown, the more force it will generate, and accordingly, the less massive the sail will need to be.*
- [305-06, ¶s 7-9] Critical issues affecting solar sail design:
 1. Anticipating Newton's 2nd Law:
Because the magnitude of the acceleration of an object is proportional to the force

acting upon it, and is inversely proportional to the object's mass, a large, lightweight, and highly photon-reflective solar sail is crucial.

2. In order to ensure as least massive a solar sail as possible, thrust must be created alternatively. One alternative involves...
 - [¶ 10] Flying closer to the sun: according to The Inverse Square Law, the farther an object's distance from the sun, the less illumination, and thus solar pressure, the object will receive.

❖ Main idea (¶s 11-17): *A variety of solar sails have been developed, one of which is successfully propelling through space, but technology has yet to promise interstellar ships powered by solar sails.*

- [306-08, ¶s 11-16] After a failed NASA commission to rendezvous a solar sail with Halley's Comet, Russia launched into orbit Znamya, a giant mirror made of lightweight reflective materials intended to illuminate portions of Earth's ground at night. Consecutive developments in solar sail technology include:
 - [¶ 13] a one hundred-foot German-manufactured sail that inspired NASA in the early 2000's to build two one-hundred foot sails made from ultra-thin materials and housed in space vacuum conditions;
 - [¶ 14] a Japanese sail, IKAROS, which was launched in 2010 as a primary propulsion system on a trajectory toward Venus;
 - [¶ 15] a small NASA sail, the NanoSail-D, which entered low Earth orbit, but was dragged down by upper-atmospheric winds;
 - [¶ 16] and a planned LightSail-1, with a similar weight but larger size to NanoSail-D, capable of pointing toward the sun.
- [¶ 17] The successes of IKAROS and NanoSail-D have led to renewed interest in solar sail technology that might make capable solar system-wide travel.

❖ Main idea (¶s 18-33): *There are several possible solutions to manufacturing immense and delicate solar sails and maintaining solar thrust in interstellar space.*

- [309, ¶ 18] Even in interstellar space, solar sails may sustain force (acceleration) by maintaining very close approaches to the Sun, and by utilizing lasers.
- [30910, ¶ 19] While great speeds attained from near solar approaches have been calculated to make an Alpha Centauri arrival possible in one thousand years, there remains critical challenges with solar sail technology, including:
 - [¶s 20-2] Manufacturing: in order to transport and sustain humans, a ship's solar sail must be extraordinarily large to support its mass. Such a sail would benefit from being built in outer space so as to avoid damaging its necessarily lightweight material during construction in Earth gravity or during an Earth launch. However,

a major challenge remains of creating an infrastructure for in-space manufacturing of solar sail parts, not to mention the difficulty of in-space manufacturing itself.

- [310, ¶ 23-4] One solution to the manufacturing problems is to build a robust sail on Earth capable of surviving a launch, but manufactured so that its heaviest part evaporates when it comes into contact with solar ultraviolet light.
- [311, ¶ 25] Another challenge with solar sail technology is that most thrust from the Sun must be acquired before a ship passes the orbit of Jupiter.
- [311, ¶s 26-8] According to physicist Robert Forward, a sixty-five Gigawatt laser with a six hundred mile diameter focusing lens, housed near Jupiter's orbit, might serve as a surrogate for sunlight that could propel a sail to a velocity of one tenth the speed of light.
- [312, ¶s 29-30] Forward suggests that a laser utilizing seven Terawatts of energy could propel a massive sail craft to Alpha Centauri in forty years as well.
- [313, ¶ 31] Forward also proves that laser light reflected from the outer sail ring can decelerate a sail craft, thus allowing for longer trip intervals.
- [313-14, ¶ 32-3] As technology advances, larger and lighter-weight sails must be built for near-term exploration of our solar system, and beamed energy must be explored as a sunlight surrogate.

Quiz/Reading Comprehension Questions:

1. Who first conceived of the idea that outer space contains a “cosmic breeze”?
 - a. Arthur Compton
 - b. Sir Arthur Eddington
 - c. Johannes Kepler
 - d. Robert Forward
2. What is the name for the momentum that sunlight creates?
 - a. solar pressure
 - b. solar thrust
 - c. photon force
 - d. solar force
3. Where in our solar system would a solar sail be too far from the sun to gather sufficient momentum?
 - a. Saturn
 - b. Mars
 - c. Uranus
 - d. Jupiter
4. What does Johnson compare to the space shuttle and the solar sail?
5. What was the purpose of the Russian Znamya mirror?
6. Why did the NanoSail-D lose low Earth orbit?
7. What are two challenges in manufacturing solar sails in outer space?
8. How does Robert Forward suggest that a solar sail be decelerated?

Answers:

1. c
2. a
3. d
4. Johnson compares the space shuttle to the hare and the solar sail to the tortoise.
5. The Znamya mirror was intended to reflect solar light in order to illuminate portions of Earth ground at night.
6. Upper atmospheric winds dragged NanoSail-D back into Earth's atmosphere.
7. There is currently no infrastructure built in space to house a solar sail factory, and transferring raw materials between Earth and space will be difficult.
8. A solar sail might be decelerated by having a detachable inner sail that uses laser light reflected from the outer ring of the sail.

THE BIG SHIP AND THE WISE OLD OWL, Sarah A. Hoyt

Major Characters:

- NIA is a member of a maintenance crew aboard a multigenerational starship. Although a young adult, she prefers to live with her parents.
- CIAR is a linguist who spends his days translating old documents from Earth. He is fascinated with nursery rhymes.
- ENNIO is a teacher's assistant who maintains and programs computers aboard the ship.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - surrogate
 - crèche
 - subversive
 - linguist
 - the root *sens-*
 - tunic
 - embryo
 - the root *bio-*
 - curiosities (*n.*)
 - mutiny
 - pedantic
 - conservative
 - encode
 - fossilized
 - gyrate
 - convoluted
 - resignation
 - agog
 - query
 - cryptic
 - sagely
 - ulterior
 - sanction
 - woebegone
 - vacillate
 - reprieve
 - acrophobia
 - inept
 - chimera
 - errant
 - dubious
 - null g
- Focus question/initiating activity: Ask your students to imagine what it might be like to be born and live an entire lifespan within a spaceship. What about humans might be different if they have no prior experience living upon Earth? Have them respond in a quick writing activity followed by a sharing of ideas.

Plot Summary:

- [pgs. 316-23] In a classroom aboard a multigenerational starship, linguist Ciar waits while computer technician Ennio makes a minor repair to a computer. Also present is Nia, a maintenance crew member, who contemplates which young man, both of which are childhood friends, she should date. Ennio plays a nursery rhyme computer program featuring an eavesdropping wise owl who can dictate directions to Alpha Centauri. Ciar

comments that, according to his archival studies of traditional rhymes, the new rhymes have been changed. When Ennio draws attention to the rhyme's preservation of an obsolete owl, Nia hypothesizes that such knowledge might be being preserved in case Earth ecology need be reestablished on another planet. While Ennio recognizes that rhymes have been changed, Ciar suggests that rhymes still maintain a stable linguistic foundation over which instructions may be encoded. Losing focus, Ennio invites Nia to a dance, and Nia accepts.

- [323-31] Nia wonders about her mother's subversive past as her mother offers an old dress for the dance. At the dance, Ciar beseeches Nia and Ennio to leave and meet him at the ship's archive. After sharing an intimate dance, Nia and Ennio make way to the archive, where Nia contemplates the enormous scope of human Earth history being translated into English by myriad workers at their desks. At his computer, Ciar is relieved to see Nia and Ennio.
- [331-335] Ciar bypasses an error message and displays a series of old and new versions of nursery rhymes, of which many of the new feature the wise owl. Ciar explains that these rhymes indicate an important event following a span of ten generations upon the starship. Ciar, however, is denied access to data not only about the ship's genealogy, but also the owl. Thinking of her grandparent's grandparents, Nia calculates that at least six generations have passed aboard the ship. Though Ennio discourages Ciar from investigating their ship's chronology any further, Ciar remains in the archive to research while Nia and Ennio return to the dance. At home, Nia inquires her mother about her family history upon the ship, discovering that at least seven generations have passed aboard.
- [335-343] Nia feverishly sets to work the next day on a minor mechanical system blackout. On her way home she is diverted by Ennio, who, uncharacteristically, gestures cautiously for Nia to follow him, leading her to a maintenance closet. Ennio informs Nia that Ciar has been arrested for a capital crime, resulting in a death penalty the following week. Ennio admits that despite the fact that Ciar was possibly arrested for researching nursery rhymes, Ennio downloaded more. Turning on a small computer, Ennio explains that after correlating all information about the wise owl from the nursery rhymes, he has inferred that the owl is another computer hidden aboard the ship. To Nia's amazement, Ennio speculates that the ship's administration does not want the ship to arrive at Alpha Centauri so that it may retain its societal power. Ennio also suggests that he has figured how to determine the location of the owl, and Nia agrees to help him find the computer later that night.
- [343-44] Nia anxiously eats dinner with her family, taking notice of light changes shifting with the fluctuation of solar reflection mirrors around the ship. After her parents go to bed, Nia sneaks out to meet Ennio.
- [343-46] After travelling through an unmaintained tunnel in the outermost of the ship, Ennio is guided by his computer to climb up the tunnel wall at a specific point. As they

climb, Nia realizes that the wall seems especially built to climb, an inference that is reassured when, well above the tunnel floor, she reaches ladder-like rungs.

- [346-48] Ennio discovers a door in the wall, and Nia opens it by handle. A light shines from behind the door, and Nia and Ennio step into the hidden room. When a calm voice asks what is being sought, Ennio directly mentions the owl, and another door opens along a wall. From this second hidden room, Nia and Ennio are transported to yet another room. In this room a voice asks what question is intended for the owl. Ennio inquires as to how many generations have lived upon the ship, while Nia asks how far the ship is from its destination. Once again, a door opens to reveal another room in which a wall becomes animated with an owl whom, after identifying itself, is realized by the shipmates as the guiding voice.
- [348-52] In conversation with the owl, Ennio and Nia discover that it had been originally hidden, even from the ship's administration, to preserve information. From a series of questions, the owl informs the shipmates that Alpha Centauri is only an Earth day away. The owl further informs the shipmates that the entire ship's colony will need to be informed, all at once, of the weightlessness caused when the ship ceased to spin in deceleration, among the location of lifeboat bays. Nia decides to configure the owl to be able to communicate with the entire ship. The owl informs Nia of Ciar's location, and that the lifeboat landers can scout landing locations once the ship slingshots around Alpha Centauri's sun. Nia and Ennio decide to risk hiding in a lifeboat lander.
- [352-54] Nia and Ennio rescue Ciar and sneak to a lifeboat, which successfully navigates them to a habitable Alpha Centauri planet. Nia suggests that her plan to inform the ship's colony of its Alpha Centauri arrival, along with the location of lifeboats, was also successful. Nia raises a family with Ennio on the planet, whose colonies are agriculturally sustained.

Quiz/Reading Comprehension Questions:

1. Historical records from the archives on Nia's ship are being translated into:
 - a. English
 - b. a new language formed by combining preexisting languages
 - c. every language that is spoken on the ship
 - d. computer code
2. According to the nursery rhyme, why might the owl need to explain the way to Alpha Centauri?
 - a. The ship's navigational computers might be destroyed.
 - b. Directions were only given to the administration, all of who may die unexpectedly.
 - c. The path to Alpha Centauri might need to change due to unforeseen cosmic obstacles.
 - d. The civilization aboard the ship might forget the purpose of their voyage.

3. Nia views herself as:
 - a. extraordinary
 - b. cowardly
 - c. average
 - d. dangerous
4. According to Nia, what is unknown about the planet to which her society is travelling?
 - a. whether its atmosphere is fully breathable
 - b. its level of biological development
 - c. whether its existing intelligent civilization will welcome Nia's society
 - d. if it is actually a myth created by the administration to create a false hope
5. Which pair of adjectives best describes the administration on Nia's ship?
 - a. secretive and domineering
 - b. transparent and democratic
 - c. primitive and spiritual
 - d. disorganized and laissez faire
6. How does Nia pass on her history to her children?
 - a. in writing
 - b. in songs
 - c. through spoken storytelling
 - d. through computer programs
7. List two powers that the administration has over the ship's inhabitants.
8. How does Nia's ship produce sunlight?
9. What does Nia believe that most people aboard her ship primarily care about?
10. According to Nia, what is the benefit of the human race expanding throughout the universe?

Answers:

1. a
2. d
3. c
4. b
5. a
6. b
7. The administration can decide how many children a woman can have, and how many "luxury rations" a person is allowed. (Other possible answers might include: The administration may investigate civilians for antisocial behavior; they do not allow premarital sex; they monitor civilian work).
8. Nia's ship uses a system of mirrors to reflect sunlight into the ship.
9. Nia believes that most of her people care primarily about obtaining luxury rations.

10. The human species will be so widespread that no single calamity can render the entire race extinct.

Critical Thinking Questions:

1. How does the way in which humans measure societal status in “The Big Ship and the Wise Old Owl” compare and contrast with how societal status is measured in “Lesser Beings”? What do people value most in each story?
2. Nia observes that her fellow shipmates are mainly concerned with personal comfort (luxury rations) and how many children they are allowed to have, and with whom. Nia remarks, however, that the ship’s lifeboats are more comfortable than the ship’s lodgings. What might this suggest about life aboard the ship?

Suggested Activity/Inquiry-Based Exploration:

1. Hoyt’s story is set within a multigenerational starship that sustains a human society with at least a partial ecosystem that includes wheat-planted fields. After reviewing concepts of multigenerational starships, ask your students to brainstorm what makes a society function, and what structures a generational starship would need to include in order to guarantee a successful long-term voyage. Consider having your students draft and debate “top ten” lists of essential societal structures. Some useful resources:
 - An article on a world seed vault can be found at the Global Crop Diversity Trust website. <http://www.croptrust.org/main/arcticseedvault.php?itemid=211>.
 - A recent article on the history of Biosphere 2, including an extreme human diet experiment, can be found at the Cabinet Magazine website. <http://www.cabinetmagazine.org/issues/41/turner.php>.
 - Information on the O’Neill cylinder and Bernal sphere concepts can be found at the National Space Society website. <http://www.nss.org/settlement/space/oneilcylinder.htm>; <http://www.nss.org/settlement/space/bernalosphere.htm>.
2. Ask your students if they remember reading or being read nursery rhymes when they were young. Have your students research nursery rhymes from other cultures and consider how these rhymes are suited particularly to the culture at hand, including how the rhymes might have changed over time. Students might work in groups and make class presentations. Some useful resources:

- An extensive database of nursery rhymes can be found at <http://www.rhymes.org.uk/>.
- The meter of “The Big Ship Sails on the Vacuum, Oh” seems to be based on “London Bridge.” Information on possible historical meanings behind “London Bridge” can be found at Wikipedia. http://en.wikipedia.org/wiki/London_bridge_is_falling_down.
- A database of nursery rhymes and children’s songs by country can be found at Mama Lisa’s World website http://www.mamalisa.com/?t=e_atoz.

SIREN SONG, Mike Resnick

Major Characters:

- FARTREKKER JONES is an eccentric and media-wary captain of the solar sail starship *Argo*.
- VLADIMIR is the co-pilot of *Argo*.
- KNIBBS is *Argo*'s navigator.

Prepare to read...

- Familiarize yourself with the following vocabulary and terms:
 - regatta
 - pundits
 - parsec
 - buoy
 - myriad
 - motive power
 - permeate

Focus activity/initiating question: Investigate with your students the layout of the Milky Way solar system. Emphasize the Asteroid Belt, and display images of the moons of Jupiter, Saturn and Uranus. Consider pairing these images with ocean sailing ships to emphasize Resnick's ocean-sailing motif.

Plot Summary:

- [pgs. 356] By the 23rd century, humanity's ability to traverse its solar system has made it grow weary of racing ships across Earth's oceans. Instead, six spaceships enter a race that begins at Earth orbit and stretches as far as Uranus' moon.
- [357-58] The *Argo*, a lone solar sail ship, catches the public's attention due to its structure and eccentric captain, FarTrekker Jones. With the *Argo* bringing up the rear, the ships soon reach Mars and continue on a predetermined trajectory to Jupiter's moon, Ganymede. FarTrekker, however, decides to regain lost time by taking a short cut through a dangerously dense section of the Asteroid Belt.
- [358-59] While the *Argo* negotiates most of the Belt without sustaining major damages, its copilot Vladimir accidentally brushes against control panel buttons while falling asleep, seemingly causing a mysterious sound to fill the ship.
- [359-60] The sound is interpreted by *Argo*'s three-man crew as a sorrowful song that each attribute to a beloved woman from which they have been separated.
- [360] Despite FarTrekker's wishes, Vladimir cannot determine the source of the song, deciding that the sound is emanating from without the ship. The men fall entranced by the song.

- [360] When FarTrekker imagines that the song is emanating from his lost love who is trying to reach him, his shipmates embrace the same theory, but with their own lost loves in mind. FarTrekker then hears his lost love’s voice in the song.
- [360-61] In an effort to trace the song’s source, FarTrekker asks his ship navigator Knibbs to check the vicinity for asteroids, of which one is found. FarTrekker realizes that the name of the asteroid, Anthemoessa, is the Greek mythological home of Sirens. Vladimir denies FarTrekker’s subtle suggestion that sirens are actually calling for the crew; however, Vladimir cannot help but agree that he hears his lost love in the melody of the song.
- [361] When Knibbs discovers that Anthemoessa was named by a widowed man, FarTrekker suggests that the *Argo* change course for the asteroid. Though Knibbs attempts to examine the potential danger of a Siren-inhabited asteroid, Vladimir is already mentioning his lost love as if she were waiting for him, and FarTrekker is fully encapsulated merely by the possibility that he might be reunited.
- [362] The shipmates agree that heading for the Anthemoessa is worthwhile. The *Argo* changes course for Anthemoessa, returning not to the race, nor planet Earth.

Quiz/Reading Comprehension Questions:

1. “Siren Song’s” narrator accuses the media of:
 - a. creating false news
 - b. borrowing ideas from other sources
 - c. reporting rumors
 - d. having a bias for a specific racing ship
2. All are rules for Great Regatta racers except:
 - a. They cannot deviate from a predetermined course
 - b. They must pass within a thousand miles of checkpoints
 - c. They cannot land on any solid surface
 - d. They cannot warn other racers of potential dangers
3. What does FarTrekker not trust?
 - a. navigational computers
 - b. his fellow crewmates
 - c. the news media
 - d. the Siren song
4. How does FarTrekker try to regain lost time in the race?
 - a. He sails around the Asteroid Belt
 - b. He sails through a dense section of the Asteroid Belt
 - c. He accelerates the *Argo* with lasers
 - d. He lightens the *Argo*’s payload

5. When does the Siren song begin to play?
 - a. When FarTrekker begins thinking of his lost love
 - b. When the *Argo* crew discovers Anthemoessa
 - c. When small asteroids begin to pelt the *Argo*
 - d. When Vladimir falls asleep over *Argo*'s control panel
6. How is news of the race being gathered?
 - a. The racing ships are sending transmissions back to Earth
 - b. Unmanned satellites are filming the race along the route
 - c. Media ships are posted along the route
 - d. Computer tracking programs are sending data to Earth from each ship
7. What emotional effect does the Siren song have on FarTrekker?
8. If Leucosia were the actual name of FarTrekker's lost love, what might she have died from? Use a dictionary to make an inference.

Answers:

1. b
2. a
3. a
4. b
5. d
6. c
7. The song reminds FarTrekker of his lost love Leucosia, but it makes him happy rather than sad.
8. Leucosia takes from the prefix *leuko-*, which may be used to refer to white blood cells. Leucosia might have died from cancer.

Critical Thinking Questions:

1. How does the motif of ocean sailing contribute to the tone of "Siren song?"
2. In your opinion, what events will suggest that humans are ready to explore space? If you think we are ready now, explain your reasoning.
3. In way ways can outer space never fundamentally change human beings?

Summary Activity/Inquiry-Based Exploration: Have your students read Book XII of Homer's *Odyssey*, in which Odysseus is lured by sirens; and Edgar Allan Poe's short story "Ligeia," in which a man is haunted by the memory of a former lover. Assign your students a prompt that begins with two quotes: "History repeats itself," and "...nothing ever truly dies. The universe wastes nothing. Everything is simply, transformed" (said by Klaatu in *The Day the Earth Stood Still*, 2008). Let the remainder of the prompt read: In an analytical essay, compare one of the assigned readings to Resnick's "Siren Song," making thematic and real-world connections.