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Terraforming from Science Fiction to Science

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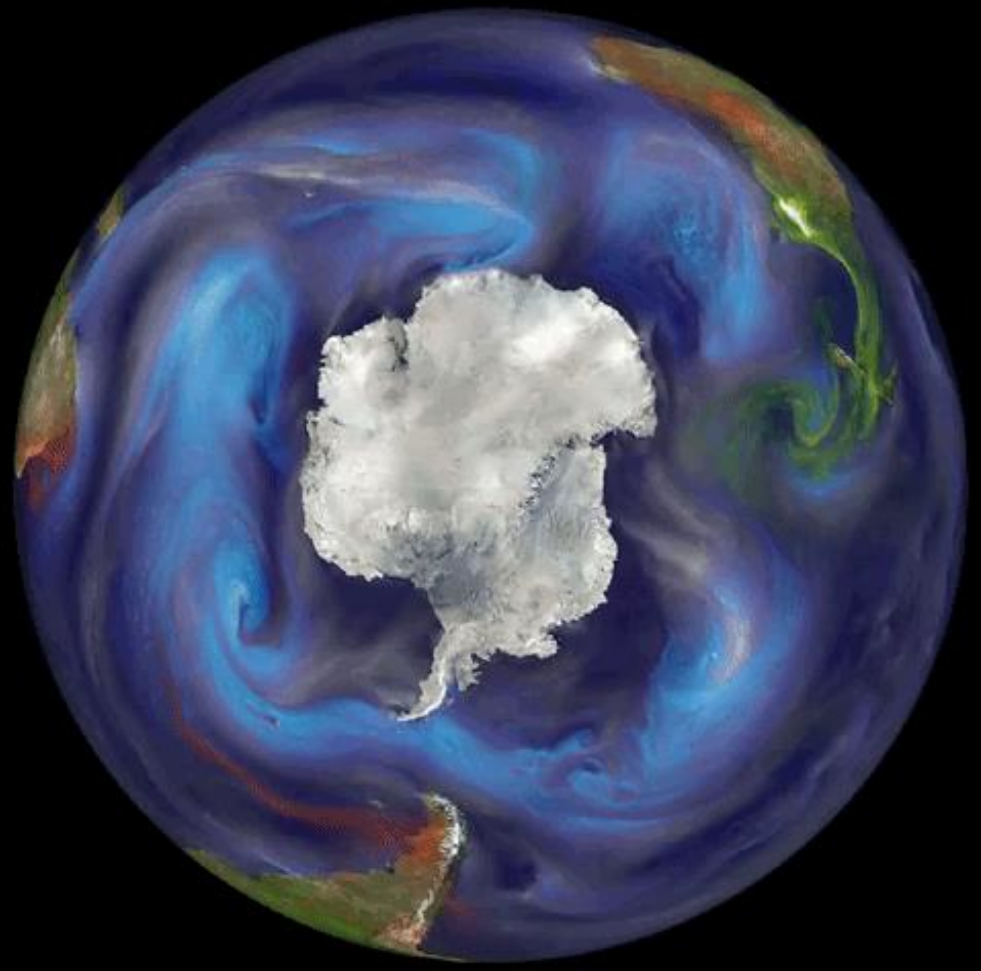


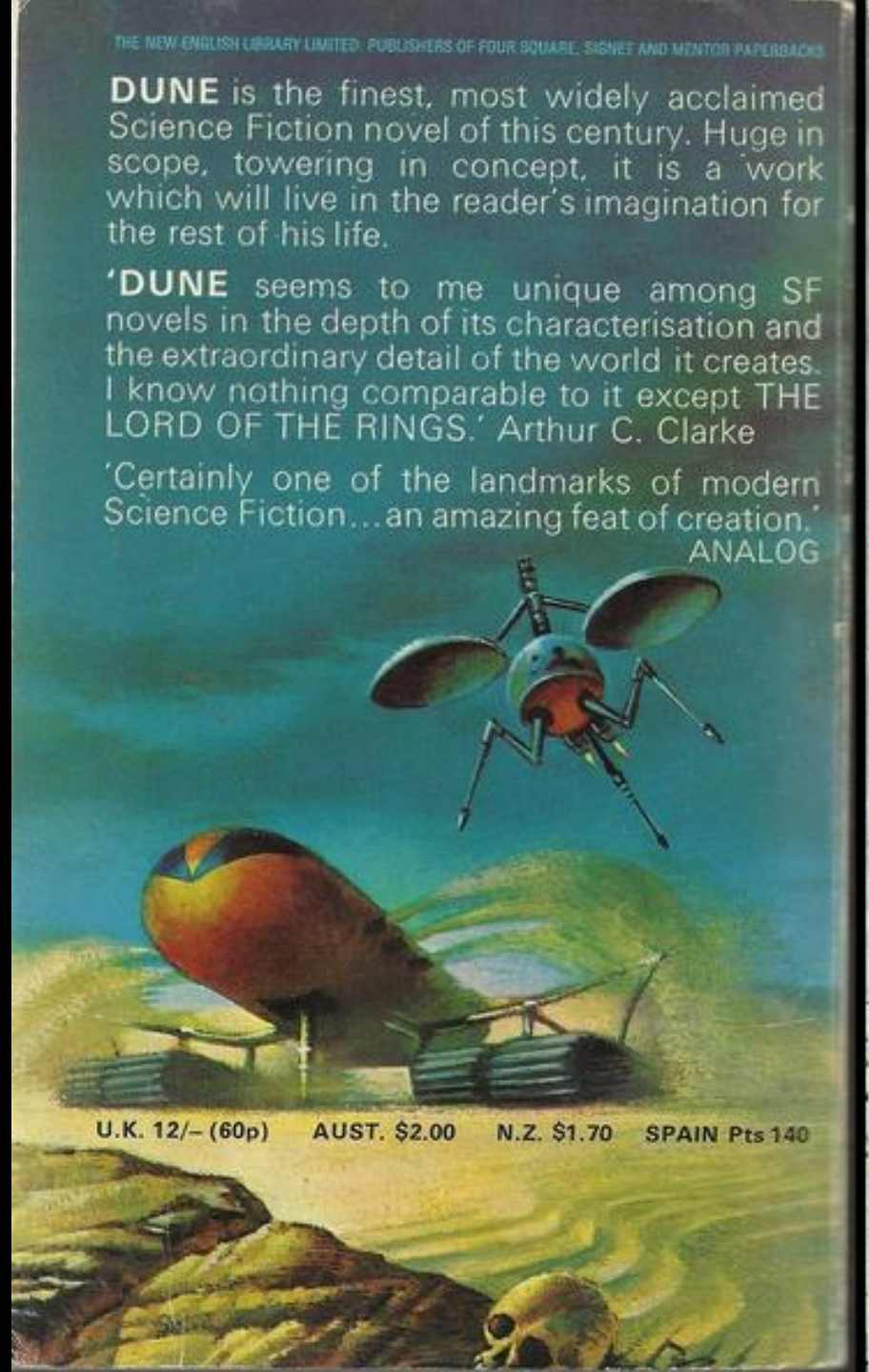
About Me

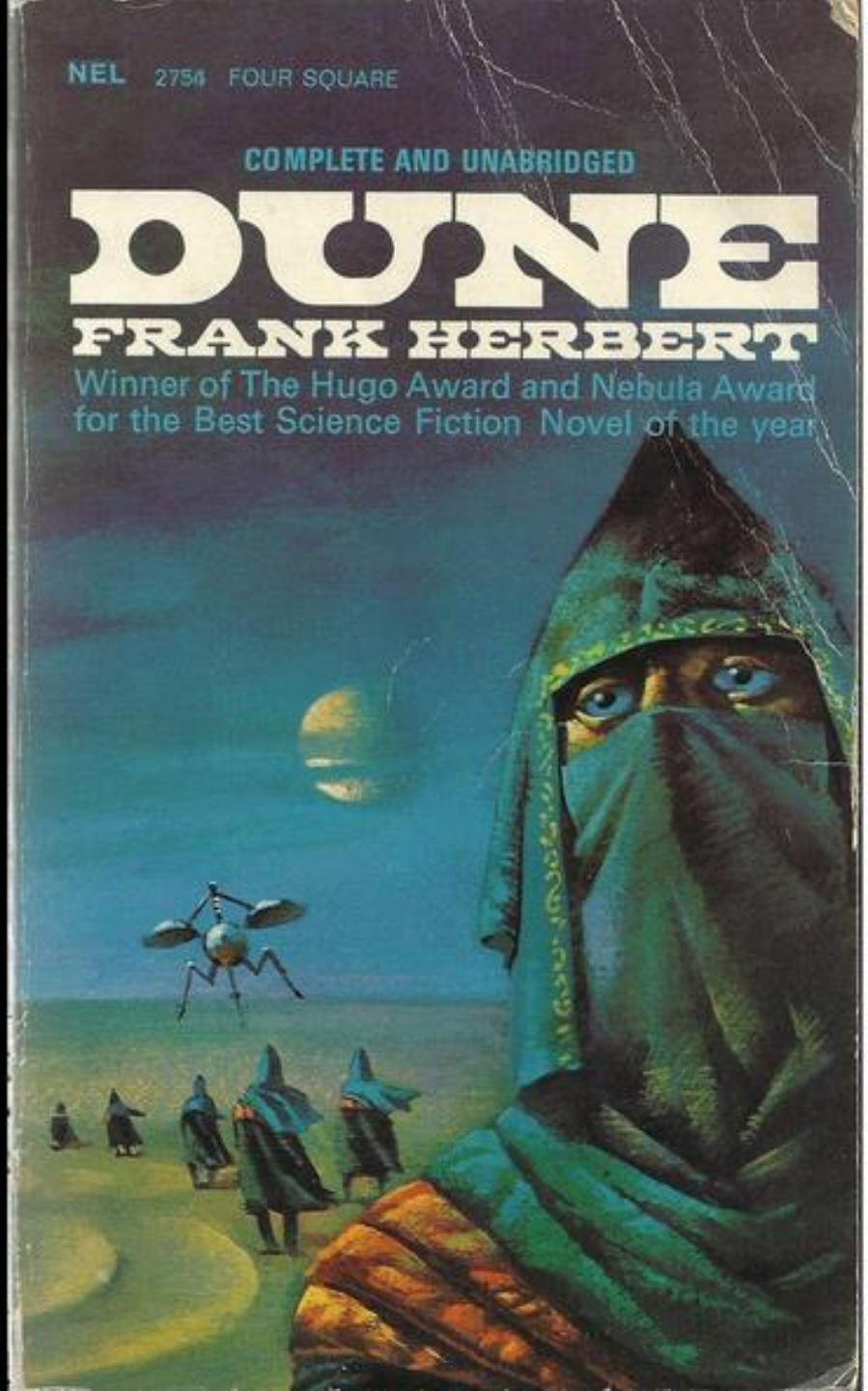
- PhD Candidate in English and Science and Technology Studies at UC Davis
- I study feedback loops between science and the arts
- Dissertation title: *Speculative Planetology: Science, Culture, and the Making of Model Worlds*
- My specialties
  - Science fiction literature and media
  - History and culture of climate modeling and planetary science

Two case studies

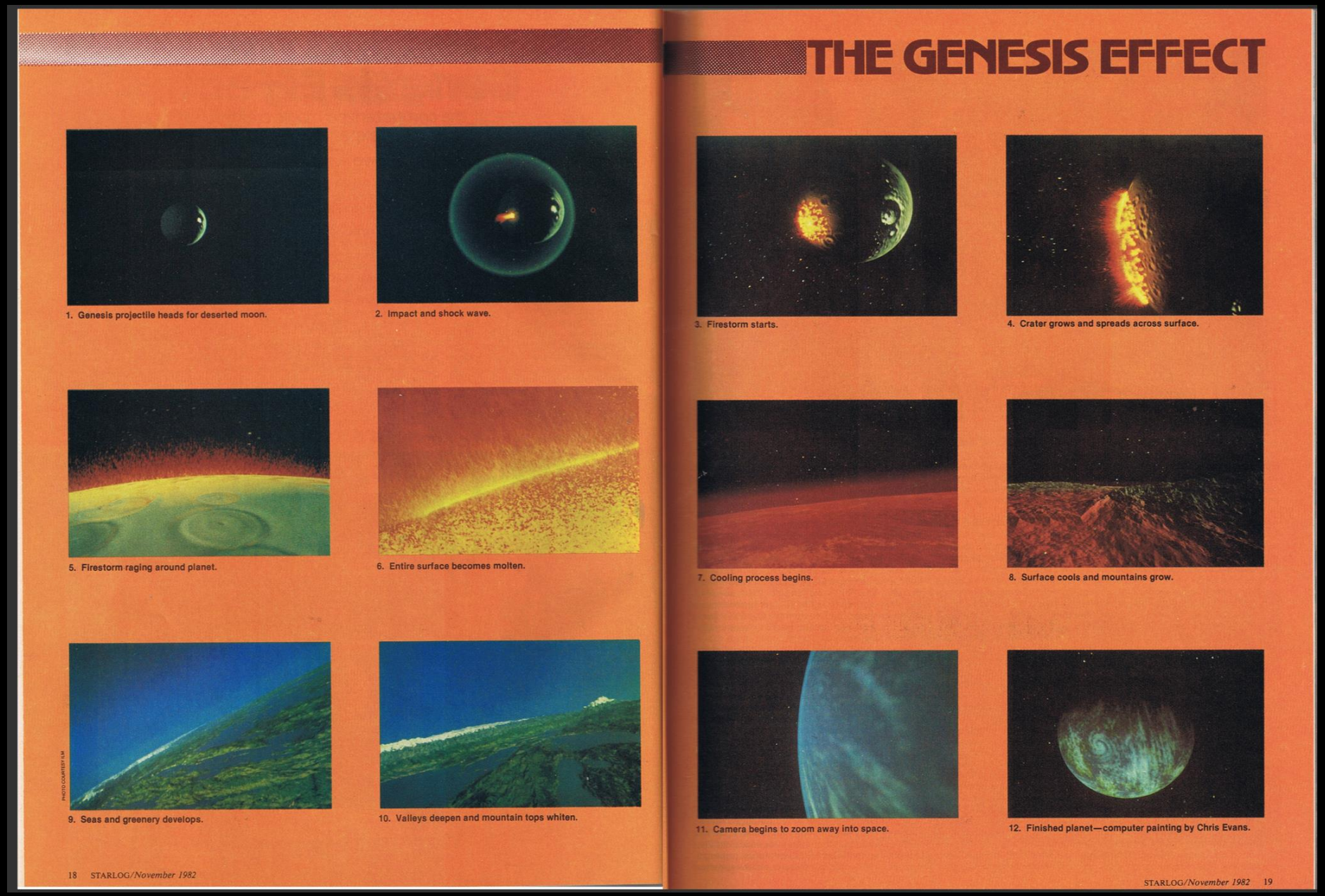
- Terraforming narratives interacted with science and technology
- The interactions created new ways of thinking about environmental and technological futures
- **Takeaway**: the stories we tell about fictional scenarios, even about terraforming imaginary worlds, help to decide what happens to our own world

Case 1:
======
Dune (1965), ecology and planetary science





Case 2:
======
"The Genesis Effect" (1982) and particle systems



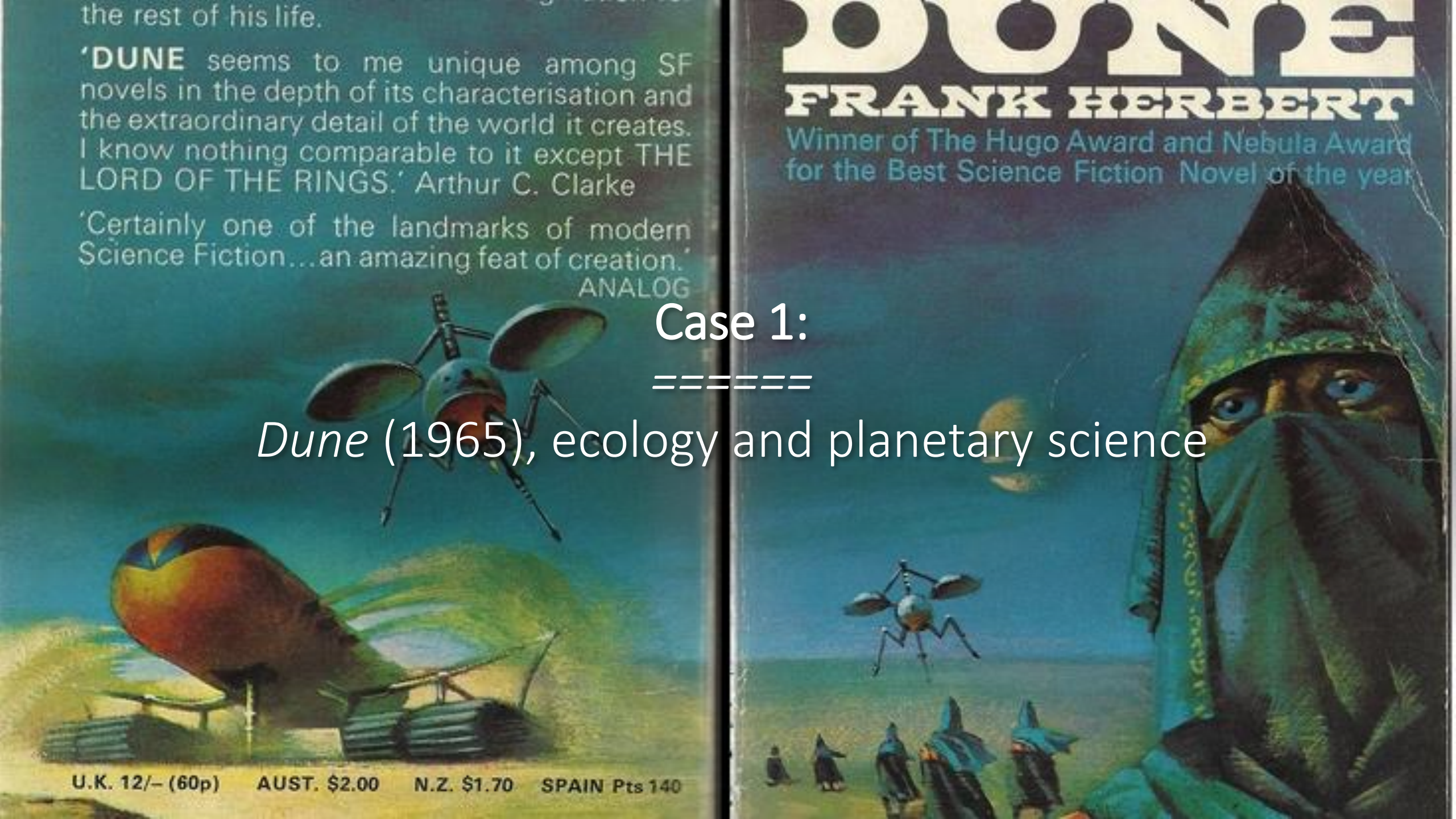
THE GENESIS EFFECT

1. Genesis projectile heads for deserted moon.
2. Impact and shock wave.
3. Firestorm starts.
4. Crater grows and spreads across surface.
5. Firestorm raging around planet.
6. Entire surface becomes molten.
7. Cooling process begins.
8. Surface cools and mountains grow.
9. Seas and greenery develops.
10. Valleys deepen and mountain tops whiten.
11. Camera begins to zoom away into space.
12. Finished planet—computer painting by Chris Evans.

PHOTO COURTESY ILM

18 STARLOG/November 1982

STARLOG/November 1982 19



Case 1:

=======

Dune (1965), ecology and planetary science

How Climate Scientists Talk about Science Fiction (Especially *Dune)*

ASTROBIOLOGY
Volume 11, Number 5, 2011

DOI: 10.1089/ast.2010.0545

Habitable Zone Limits for Dry Planets

Yutaka Abe,[1] Ayako Abe-Ouchi,[2] Norman H. Sleep,[3] and Kevin J. Zahnle[4]

Abstract

Most discussion of habitable planets has focused on Earth-like planets with globally abundant liquid
an "aqua planet" like Earth, the surface freezes if far from its sun, and the water vapor greenhouse
away if too close. Here we show that "land planets" (desert worlds with limited surface water) h
habitable zones than aqua planets. For planets at the inner edge of the habitable zone, a land plan

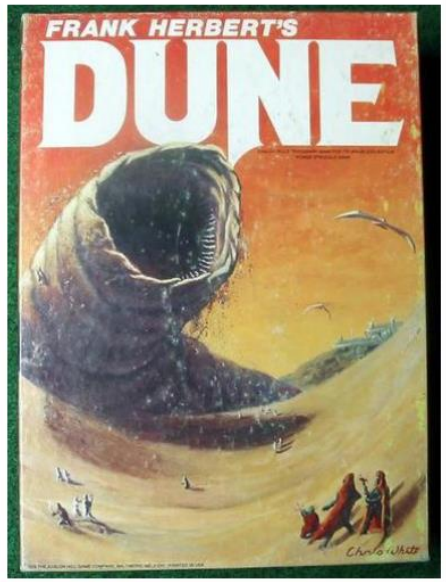
“Habitable Zone Limits for Dry Planets”
by Abe et. al

“We can imagine another kind of habitable planet that has only a small amount of water and no oceans; it might be covered by vast dry deserts, but it might also have locally abundant water. We call such a dry planet a ‘‘land planet.’’ The fictional planet known as Arrakis or Dune (*Dune*, Herbert, 1965) provides an exceptionally well-developed example of a habitable land planet. In its particulars, Dune resembles a bigger, warmer Mars with a breathable oxygen atmosphere. Like Mars, Dune is depicted as a parched desert planet, but there are signs that water flowed in the prehistoric past. Dune has small water ice caps at the poles and more extensive deep polar aquifers. The tropics are exceedingly dry, but the polar regions are cool enough and moist enough to have morning dew” (443).

Real-life sci-fi world #5: a Dune planet (Arrakis)

Sean Raymond / October 10, 2014

Welcome to Real-life Sci-fi worlds. I use science to explore life-bearing worlds that are the settings for science fiction stories. Up today: a desert planet like Arrakis from the classic Dune books (and the movie and miniseries). A tribute for author Frank Herbert's birthday (a couple days late).



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Conditions for habitable planets
Galactic neighborhood
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Sean's research
Solar System

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A sustainable planet needs scientists to think ahead

Globalization means that Earth's life-support system can no longer be treated as separate from the socio-economic system, says **Sybil Seitzinger**.

rbert's 1965 science-fiction classic *Dune*, the number-
n on the planet is held not by a politician, but by a plan-
gist. His job is to oversee the long-term conversion of
et to a lush biosphere — a role demanding formidable
.

e human population is set to top 9 billion within two
eanwhile, we are altering, in profound and uncontrolled
gical, physical and chemical processes of ecosystems on
ving population will depend. Gordon Conway, former

has been an explosion in our knowledge of Earth as a complex system. One conclusion is clear: our behaviour will shape our future.

Despite these advances, the UN still doesn't seem to see that Earth's restless and powerful social system operates within a complex and intricately linked ecological system — let alone manage it. The UN system currently includes more than 500 international treaties and agreements related to the environment. Although the current climate talks in Cancún, Mexico, are being held under the UN's Framework Convention on Climate Change, its related Millennium Development

“SFnal” climate science?

I do take advantage of a somewhat SFnal view of the universe in doing my research. That is, I’m trying to understand, say, the earth’s climate. That’s only one place with one particular set of conditions. What (the SF-fan in me asks) would it be like if the earth rotated much faster, more slowly, if the sun produced less UV (hence less ozone on earth, hence less greenhouse effect in the stratosphere, hence …?), if the earth were farther away/closer in, and so on. I can’t say that it’s resulted in any journal articles that I wouldn’t have written anyhow, but it does make it easier for me to, say, read paleoclimate papers (the earth did rotate faster in the past, sea level has been much higher and lower than present, …)

Robert Grumbine, *More Grumbine Science* blog

An “sfnal” way of thinking

- Imbrication of history of climate modeling with history of science fiction
- Standard model of climate has few requirements:
  - Top of atmosphere energy balance
  - Convection model of energy transfer
- This was surprisingly difficult for early climate science to get right*

*credit due to R.T. Pierrehumbert’s Tyndall lecture for this observation

24 March 1961, Volume 133, Number 3456

SCIENCE

The state of our knowledge of Venus is amply illustrated by the fact that the Carboniferous swamp, the wind-swept desert, the planetary oil field, and the global Seltzer ocean each have their serious proponents, and **those planning eventual manned expeditions to Venus must be exceedingly perplexed over whether to send along a paleobotanist, a mineralogist, a petroleum geologist, or a deep-sea diver** (849).

surface, and possible biology of the nearest planet.

Carl Sagan

The launching of the Soviet interplanetary vehicle toward Venus on 12 February 1961 opens a new era in planetary studies. This article is an assessment of current knowledge of Venus at the dawn of this era.

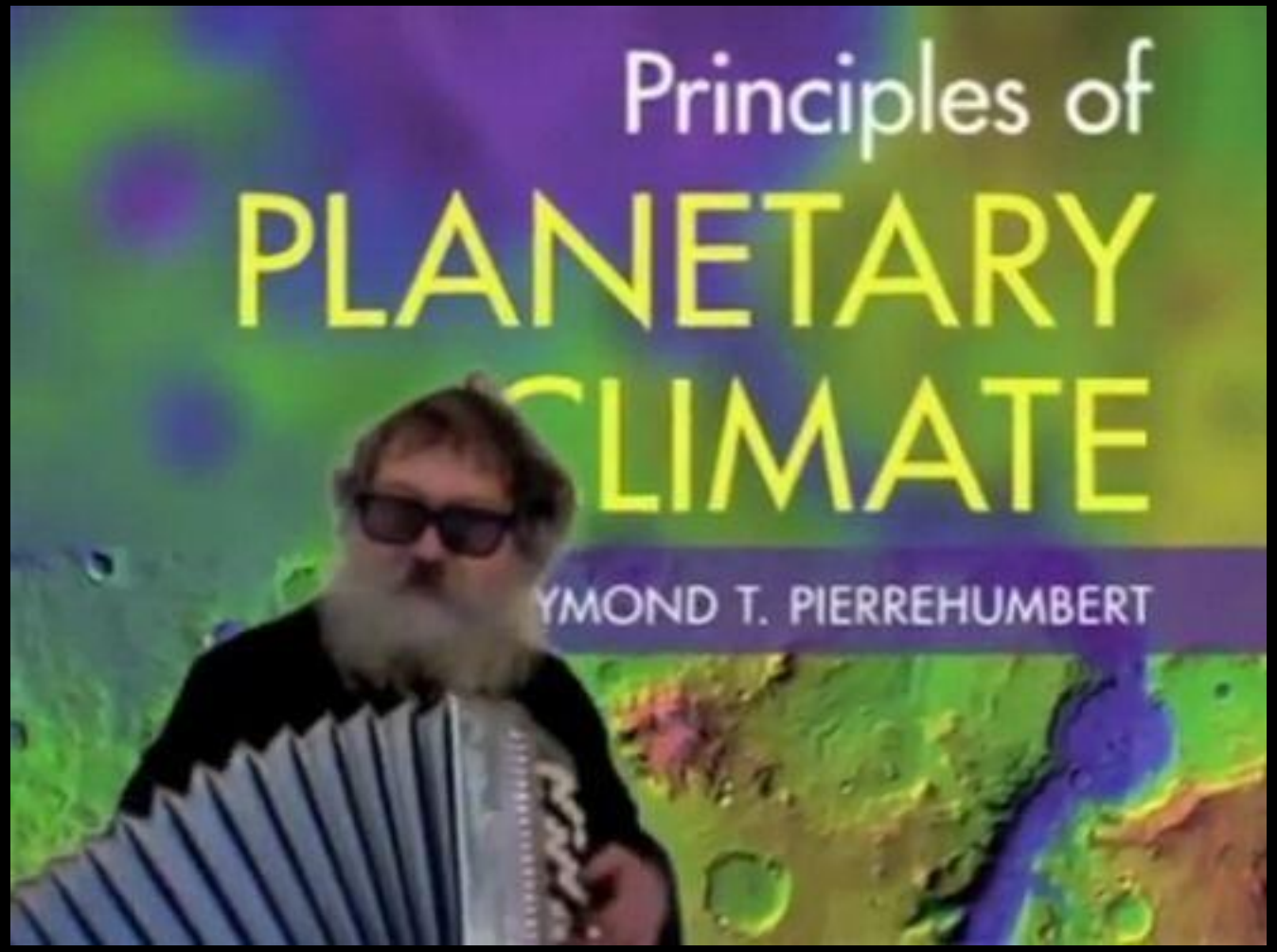
thetical Carboniferous swamp was generally abandoned, to be replaced by an arid planetary desert, overlain by clouds of dust from the wind-swept surface (*3*) (Fig. 1). The arid surface also explained the great abundance of

picture of the atmosphere and surface of Venus.

Composition of the Atmosphere

Only the portions of the Cytherean atmosphere which are above the cloud layer are accessible to spectroscopic investigation. Since the cloud layer may be situated tens of kilometers above the surface (see the discussion below), the spectroscopic data are not necessarily

Raymond T. Pierrehumbert



"Science Fiction Atmospheres"

- R.T. Pierrehumbert
- *Bulletin of the American Meteorological Society,* May 2005

the ground. But how is the aquifer recharged if it never rains? My best guess is that Dune is a dying world, with slow leakage of water into an atmosphere that is becoming gradually warmer on account of the water vapor greenhouse effect. A word of warning to those Dune scientists to wish to re-engineer the climate to bring on rain and surface water: if they succeed, they will almost certainly precipitate a runaway greenhouse. If Dune is already in a habitable temperature range without much water vapor greenhouse effect, introducing an ocean is likely to be fatal.

Dune's science fiction atmosphere

Pierrehumbert, 2005

Why is *Dune* so important to planetary scientists?

- Feedback loop:
- We've seen planetary scientists interested in science fiction
  - Because of the way that its thinking mirrors/supplements scientific planetary thinking
  - A lot of *Dune* examples
- Obviously, science fiction authors are also really interested in science.
  - How did Frank Herbert transform the science of his own moment to get *Dune?*

To the people whose labors go beyond ideas into the realm of "real materials" —to the dry-land ecologists, wherever they may be, in whatever time they work, this effort at prediction is dedicated in humility and admiration.

Controlling Coastal Sand Dunes in the Pacific Northwest

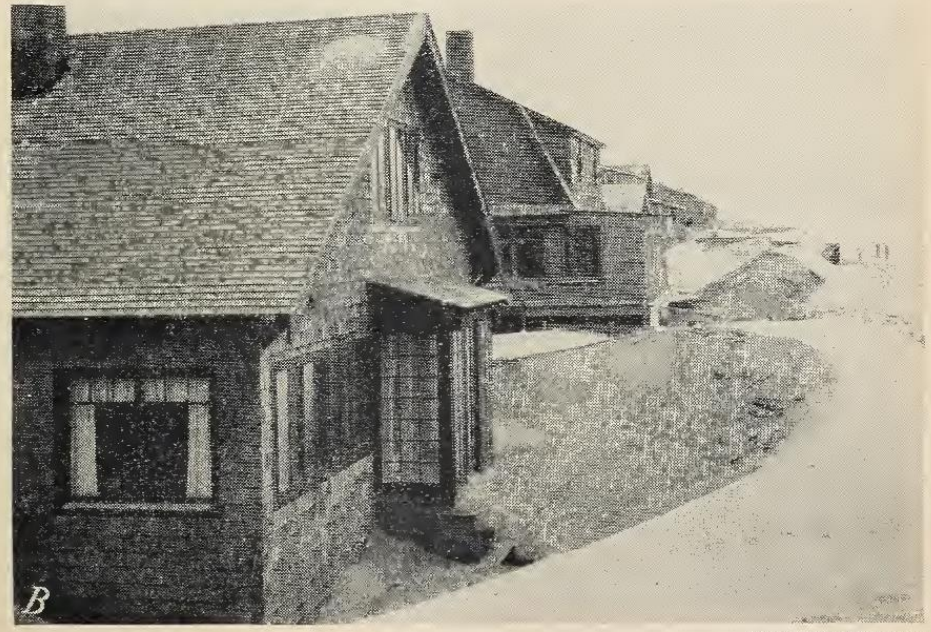
WILLARD T. McLAUGHLIN, Assistant Soil Conservationist
and
ROBERT L. BROWN, Assistant Forester
Nursery Division, Soil Conservation Service

For sale by the Superintendent of Documents, Washington, D. C., Price 10 cents

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C., SEPTEMBER 1942

at Mercer Lake Recreation Camp, just north of Florence, Oreg., where the dunes were encroaching on the timber and camp.



OREG-35012; OREG-35054

FIGURE 1.—Uncontrolled dune sand migrating inland on the Clatsop Plains dune area and destroying, *A*, a Sitka spruce forest and, *B*, valuable homes.

OREG-35162

FIGURE 16.—A field the first year after planting to European beachgrass. The planting stock, projecting about 8 inches above the sand level, decreases the wind velocity and causes sand deposition if the spacing is correct and the planting is maintained.

Terraforming

"Our first goal on Arrakis," his father said, "is grassland provinces. We will start with these mutated poverty grasses. When we have moisture locked in grasslands, we'll move on to start upland forests, then a few open bodies of water—small at first—and situated along lines of prevailing winds with windtrap moisture precipitators spaced in the lines to recapture what the wind steals. We must create a true sirocco—a moist wind—but we will never get away from the necessity for windtraps."

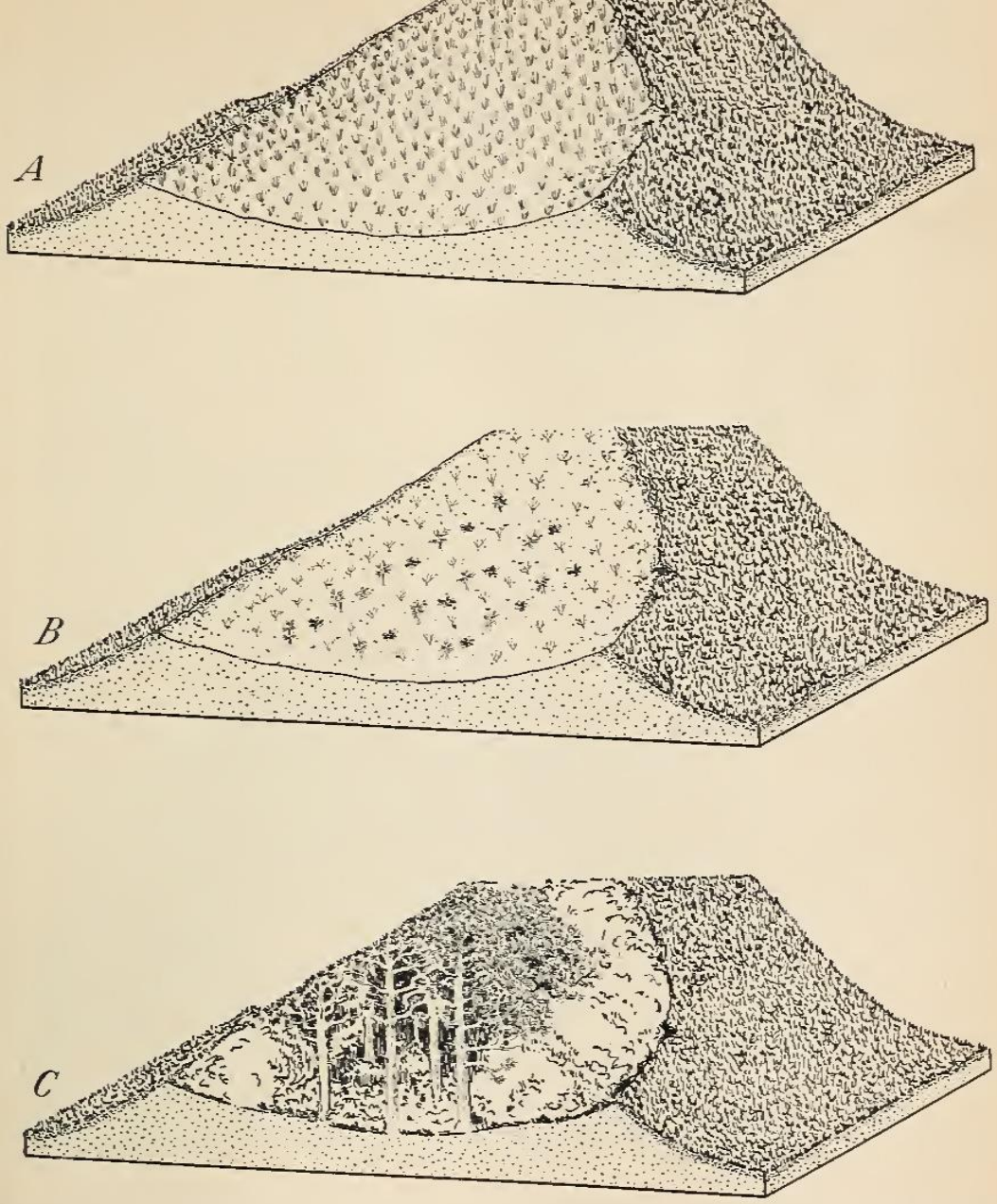
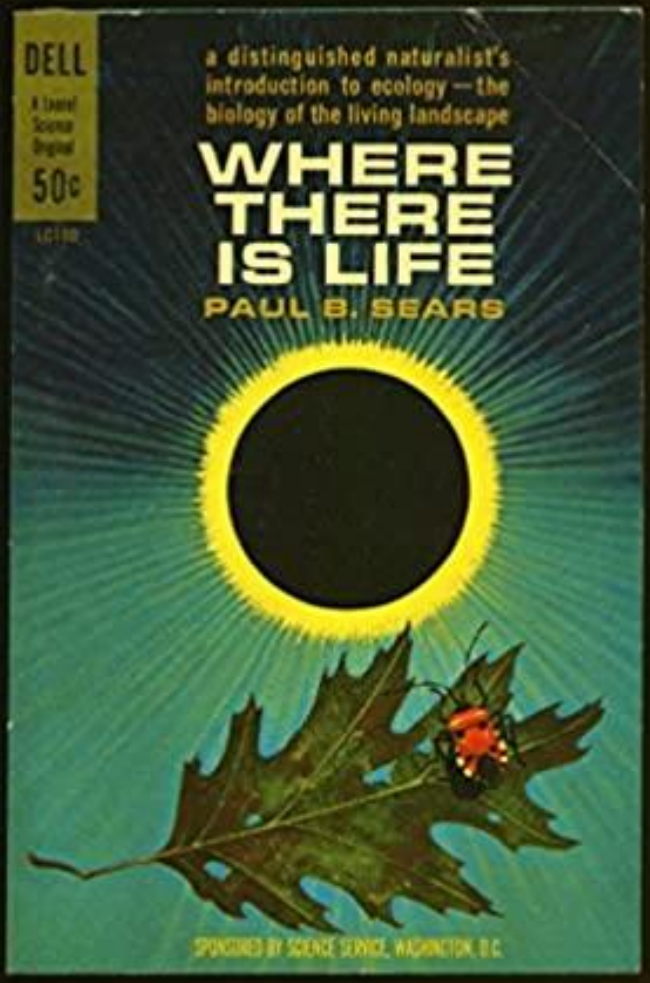


FIGURE 21.—The treatment of a gap in the dune ridge caused by trailing of livestock. *A*, The gap is planted to beachgrass partially to stabilize the sand. *B*, Pines have been introduced, together with Scotch broom as a nurse crop (grass is omitted in drawing). *C*. The mature planting tends to conform to the contours of the surrounding topography because of the wind.


DELL
A Laurel Science Original
50c
a distinguished naturalist's introduction to ecology — the biology of the living landscape
WHERE THERE IS LIFE
PAUL B. SEARS
SPONSORED BY SCIENCE SERVICE, WASHINGTON, D.C.

In *Where There is Life*	In *Dune*
"Cowles saw how vegetation was largely **determined at first by raw physical forces**, then gradually **established** **itself** and at length **became a controlling influence** that tended [...] to stabilize the earth's surface" (97).	Vegetation and animal changes will be **determined at first by the raw physical forces** we manipulate. As they **establish** **themselves**, though, our changes will **become controlling influences** in their own right (445).

In *Where There is Life*	In *Dune*
This assurance seems to satisfy many who forget that, beyond a certain critical point, freedom diminishes as numbers increase within a finite space. This is as true of humans on a continent as of gas molecules in a sealed flask (23).	Beyond a critical point within a finite space, freedom diminishes as numbers increase. This is as true of humans in the finite space of a planetary ecosystem as it is of gas molecules in a sealed flask (797).

In *Where There is Life*	In *Dune*
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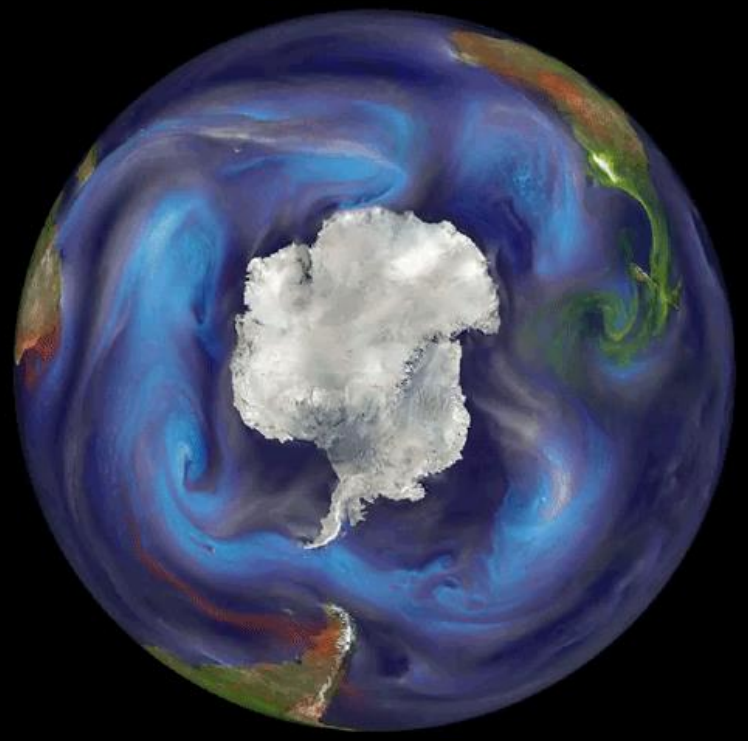
In *Where There is Life*	In *Dune*
“The Crusades, which had become a **system of mutual pillage and extortion**, also helped create great mercantile and shipping cities in the north of Italy” (194).	"The historical **system of mutual pillage and extortion** stops here on Arrakis," his father said.

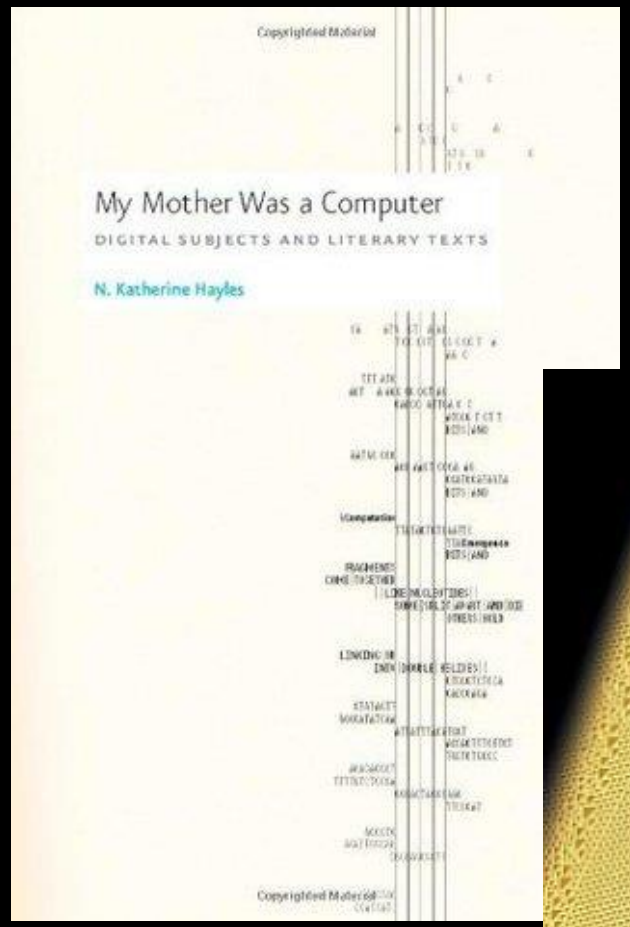
Scaling up

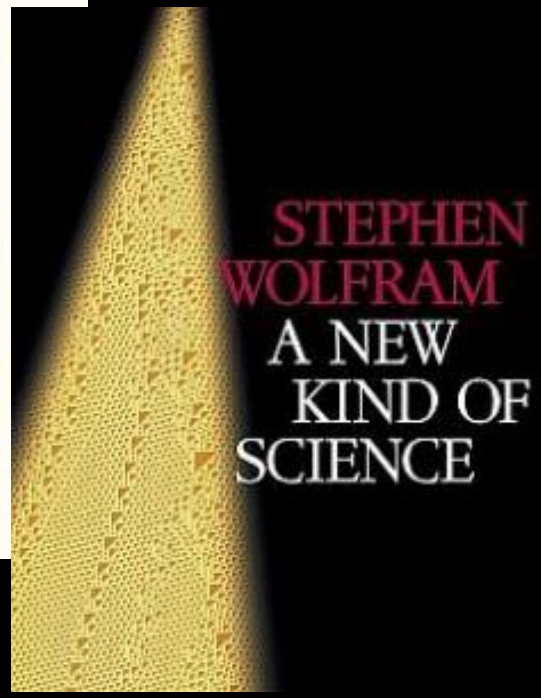
- A planet has “climates” → a planet has a “climate”
- Working ecology (like the USDA dune project) → planetary ecology



The Speculative Atmosphere in Computer Graphics circa 1985

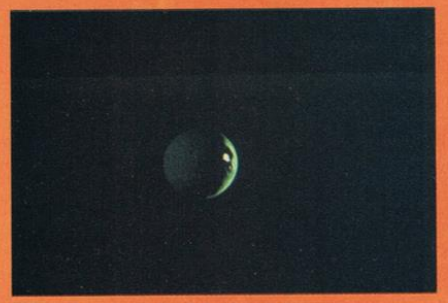
The Computational Universe





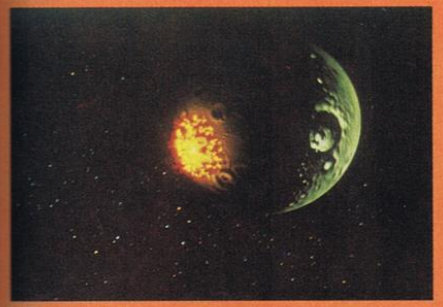
Karl Sims, “Evolved Virtual Creatures,” 1994

THE GENESIS EFFECT



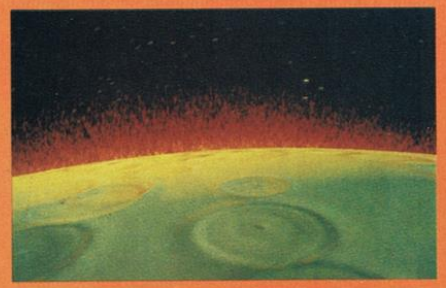
1. Genesis projectile heads for deserted moon.

2. Impact and shock wave.

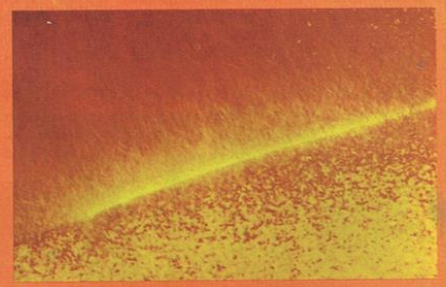


3. Firestorm starts.

4. Crater grows and spreads across surface.



5. Firestorm raging around planet.



6. Entire surface becomes molten.

7. Cooling process begins.

8. Surface cools and mountains grow.

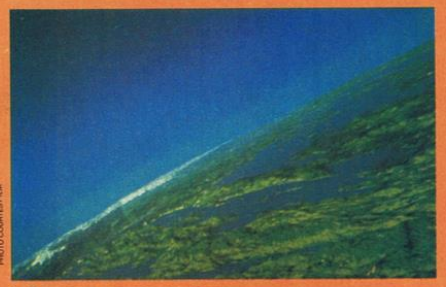
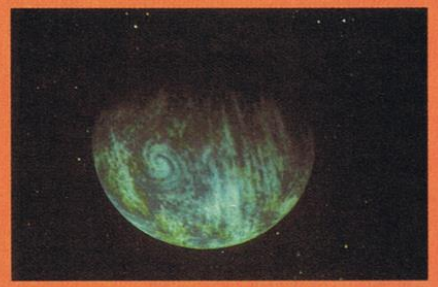


PHOTO COURTESY ILM

9. Seas and greenery develops.

10. Valleys deepen and mountain tops whiten.

11. Camera begins to zoom away into space.



12. Finished planet—computer painting by Chris Evans.

SECURITY TAPE

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The Lucasfilm Computer Graphics Team

“Genesis effect”

DR MARCUS: “Stage Three will involve the process on a planetary scale. It is our intention to introduce the Genesis device into the pre-selected area of a lifeless space body, such a moon or other dead form. The device is delivered, instantaneously causing what we call the Genesis Effect. Matter is reorganized with life-generating results.”

The computer graphics group of the Lucasfilm Computer Division, 1984 (L–R): Loren Carpenter, Bill Reeves, Ed Catmull (vice president, Computer Division), Alvy Ray Smith (director of computer graphics research), Rob Cook, John Lasseter, Eben Ostby, David Salesin, Craig Good, and Sam Leffler. Not pictured: David DiFrancesco, Tom Duff, Tom Porter.

Courtesy of Alvy Ray Smith

Particle Systems—A Technique for Modeling a Class of Fuzzy Objects

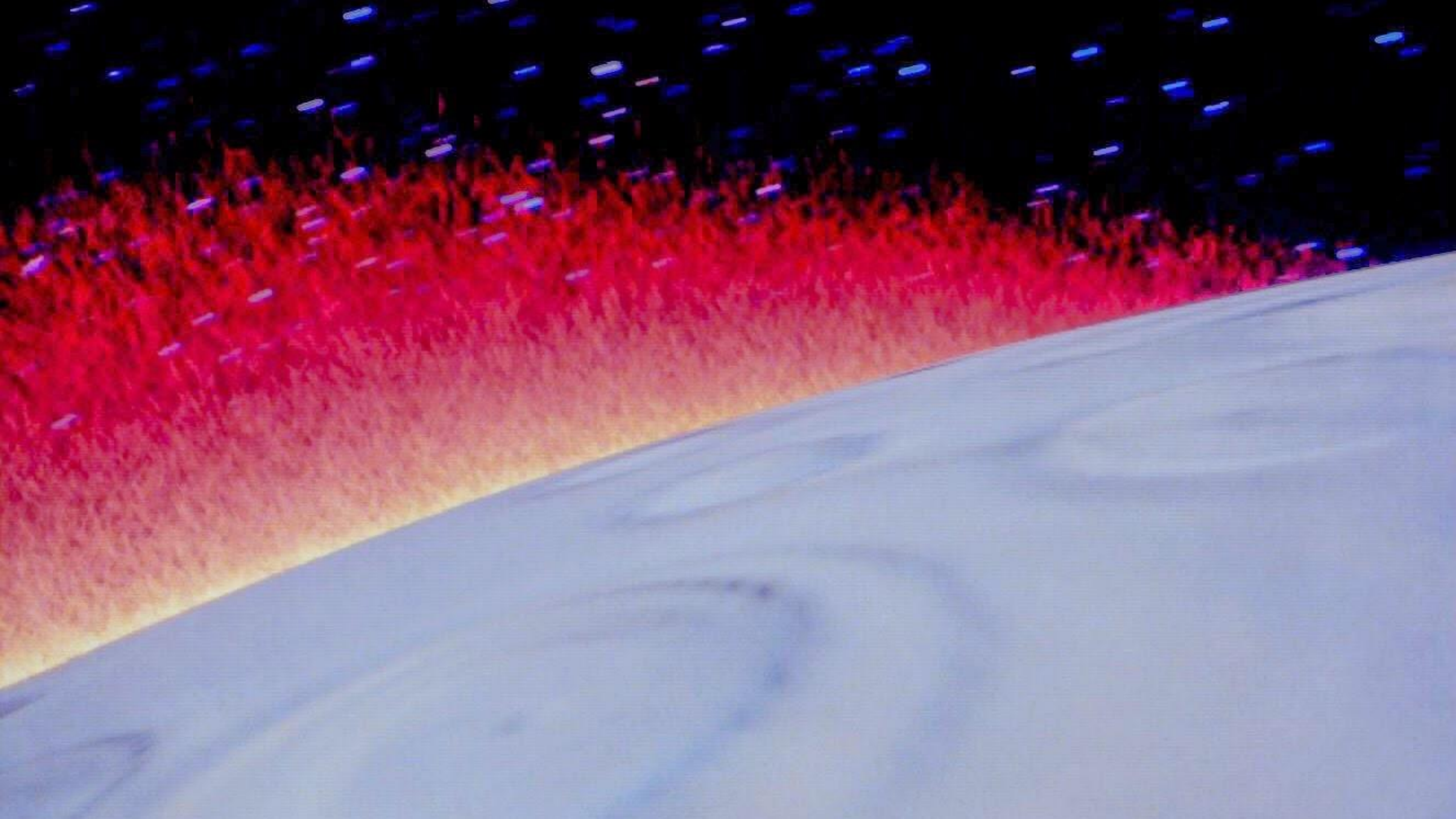
WILLIAM T. REEVES
Lucasfilm Ltd

This paper introduces particle systems—a method for modeling fuzzy objects such as fire, clouds, and

4.3 Grass

To model grass, we use an explosive type of particle system, similar to that used in the Genesis Effect. Instead of drawing particles as little streaks, the parabolic

are used to generate and control the many particles within a particle system. The application of particle systems to the wall of fire element from the Genesis Demo sequence of the film *Star Trek II: The Wrath of Khan* [10] is presented.



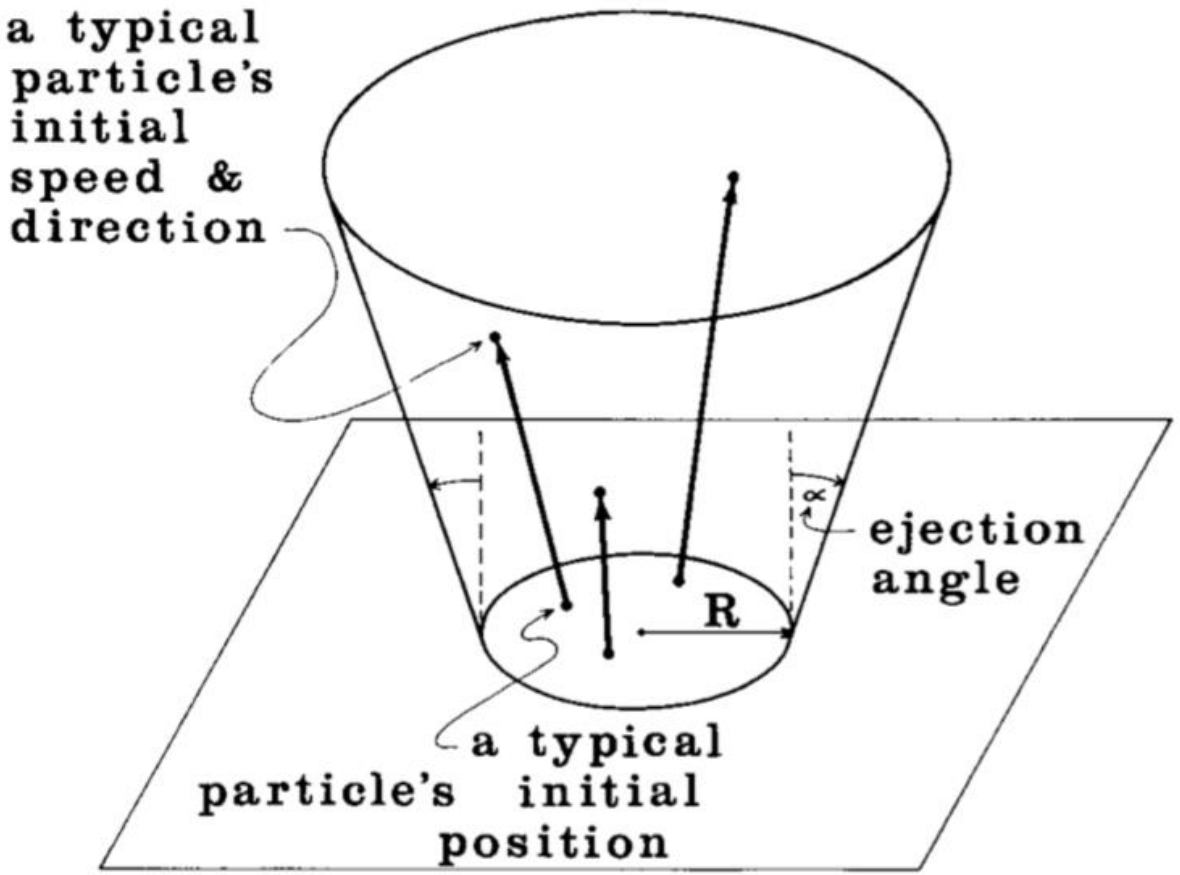


Fig. 3. Form of an explosion-like particle system.

Particle Systems—A Technique for Modeling a Class of Fuzzy Objects

WILLIAM T. REEVES
Lucasfilm Ltd

its volume. Second, a particle system is not a static entity. Its particles change form and move with the passage of time. New particles are "born" and old

a period of time, particles are generated into the system, move and change form within the system, and die from the system. The resulting model is able to represent motion, changes of form, and

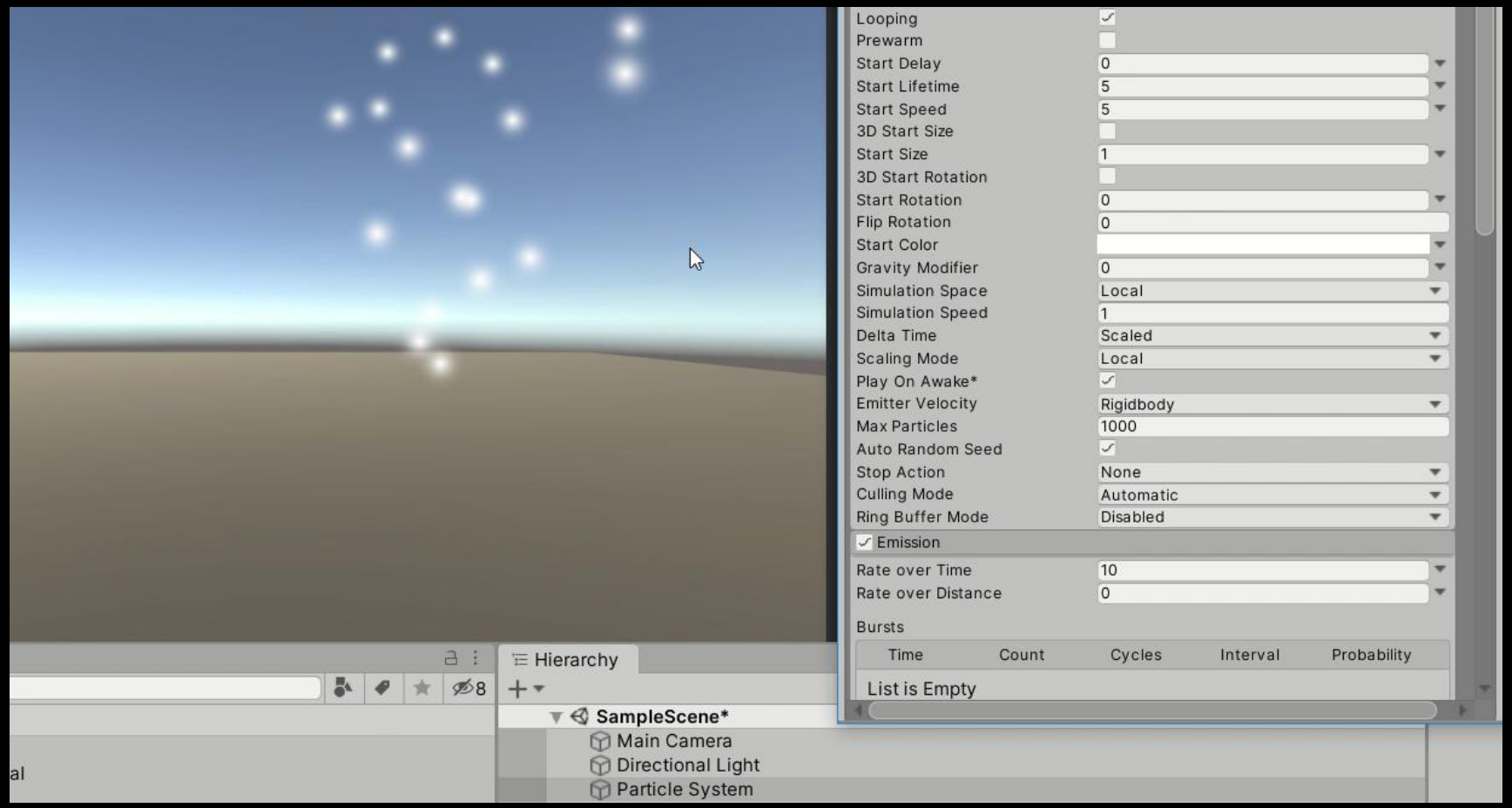
Third, particle systems model objects that are "alive," that is, they change form over a period of time. It is difficult to represent complex dynamics of this form with surface-based modeling techniques.

Modeling objects as collections of particles is not a new idea. Fifteen years ago

SPOCK: “It literally is Genesis.”

KIRK: “The power of creation.”

Particle Systems as natural phenomena?



Combining Physical and Visual Simulation - Creation of the Planet Jupiter for the Film "2010"

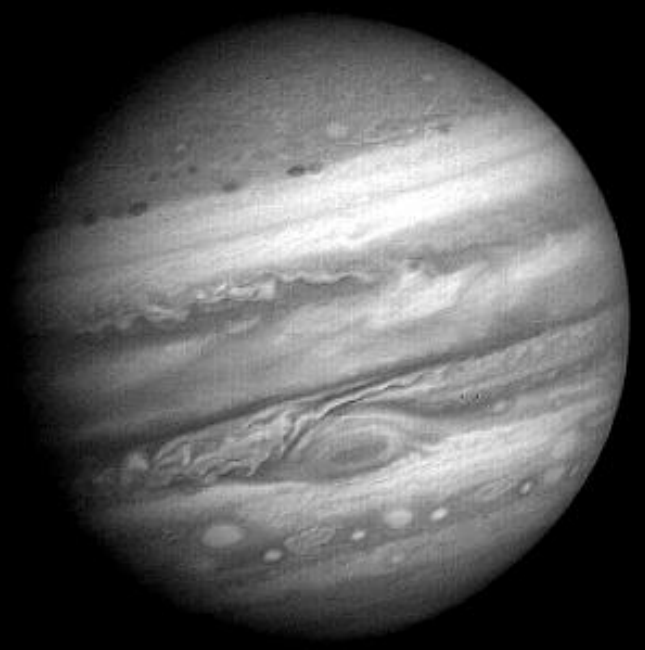
Larry Yaeger and Craig Upson
Digital Productions

Robert Myers
Poseidon Research

1. Abstract

By integrating physical simulation, in the form of numerical fluid dynamics, with visual simulation, in the form of particle rendering, texture mapping and traditional polygonal modeling techniques, we have achieved a uniquely realistic and organic special effects sequence of a planetary atmospheric flow. This paper examines the selection, implementation, and application of these techniques, known collectively as VORTEX, to produce the moving images of the planet Jupiter in the film "2010." Details of the generation of the flow

renderer is not a final product, but serves as a texture map in a polygonal rendering system. Our texture mapping techniques are based more on the seminal works by Catmull [4] and Blinn and Newell [2] than on later efforts such as Williams [15] and Crow [5]. Our polygonal rendering model is based on a hidden surface algorithm most resembling Bouknight's [3], though any of a variety of other renderers would have served [13, 9, 12, 14]. It is the fact and methodology of combining a complex physical model with high resolution computer graphics that represents a significant development in the field of visual simulation.



“As a result of television coverage of these fly-bys and the subsequent image analysis, the public also has certain expectations about the general behavior of the planet's atmosphere. We had selected a fluid dynamic technique that would deliver this realistic motion [but] this beginning vorticity state is quite important and must match up with the desired visual features to assure the proper advection.”

physics and phenomenology of vision, we have produced strikingly realistic images of a natural, but currently unobservable phenomenon. With the advent

belying their computer graphic origins. Almost everyone has had the occasion to notice an oil slick on moving water, with its swirling rainbow hues, or a dollop of cream poured into a black cup of coffee, with the subsequent rolling filaments of light and dark. These motions are recalled--with good reason, since the physics are similar--when watching the cloud motions of the simulated Jupiter. It is not claimed that the fluid dynamics models utilized in the VORTEX system accurately portray the physics of the atmosphere of Jupiter. Yet the model is not entirely ad hoc either, and it does provide a fundamentally accurate portrayal of fluid motion. It is this natural authenticity that helps viewers to willingly suspend disbelief and to imagine themselves actually watching the great planet Jupiter swirl and churn before their eyes.

Thank you!

kebuse@ucdavis.edu