Phase I Report: Customizable, Reprogrammable, Food Preparation, Production and Invention System

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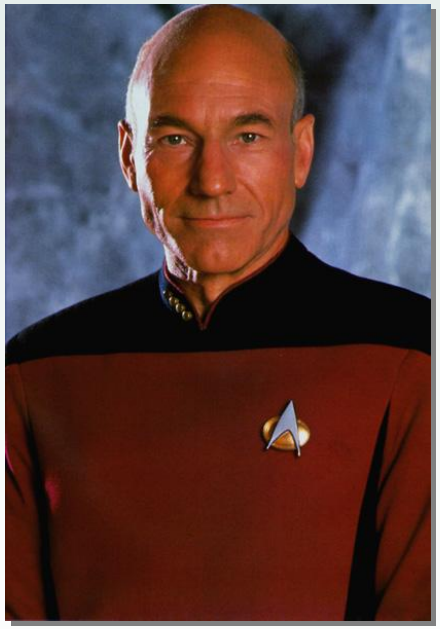
“Food is the quintessential habitability issue, whether onboard a wooden ship locked in the polar ice, a commercial airliner, or a spacecraft.”

Jack Stuster, *Bold Endeavors*

Project Objective

- Apply *Interactive Evolution* to the problem of food design during space missions.



"Tea, Earl Grey, hot."

Icosystem Practice Areas

- Consumer behavior
- Resource allocation
- Process analysis and improvement
- Distributed control
- Interactive Search and Design

Icosystem partial client List

Corporate:

- Aventis
- BP
- DuPont
- Eli Lilly
- Humana
- La Poste
- PepsiCo
- Schlumberger
- Unilever

Government:

- Air Force Research Lab
- U.S. Army
- DARPA
- DISA
- IDA
- NASA
- NUWC
- OFT
- ONR

What does this have to do with space food???

- No food expertise
- No space expertise

Icosystem Practice Areas

- Consumer behavior
- Resource allocation
- Process analysis and improvement
- Distributed control
- Interactive Search and Design

Interactive Search / Evolution

- A powerful technique to do search when “you don’t know what you are looking for but you’ll recognize it when you see it.”
- Ideally suited when search criteria include *subjective evaluation*.

Proposed Approach

- Develop a *food grammar* using ingredient combinations and transformations
- Identify and design *elementary building blocks* ("food phonemes")
- Determine necessary *physical and chemical specifications* for implementation
- Discover *reverse mapping* from desired food to generative description
- Create *novel foods* with desirable properties (texture, taste, nutrition, ...)

Proposal Feedback

- Overly ambitious objectives: focus on what can be done with reasonable subset of ingredients, rather than inventing entirely novel foods.
- Need to assemble a team of experts from the relevant disciplines.
- Use expert guidance to prepare Phase II proposal submission.

Phase I Achievements

Phase I Achievements

- Assembled team of domain experts
- Organized a workshop
- Identified pressing issues and limitations
- Investigated existing and novel food preparation technologies
- Designed a prototype tool to search for food recipes

Workshop Attendees

- Charles Bourland
  - NASA Food Technology Commercial Space Center at Iowa State University
- Malcom Bourne
  - Professor Emeritus, Department of Food Science and Technology, Cornell University
- Homaro Cantu
  - Executive Chef at *Moto Restaurant*, food innovator, principal of Cantu Designs
- Leroy Chiao
  - Former NASA astronaut, commander of ISS expedition 10

Workshop Attendees (2)

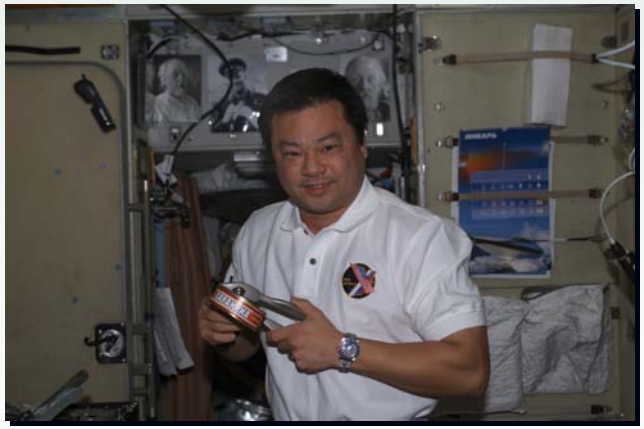
- Dan Goldwater
  - Squid Labs - engineering design & prototyping
- Lydia Itoi
  - Freelance writer and food critic
- David Julian McClements
  - Professor of Food Science, University of Massachusetts at Amherst
- Harold McGee
  - Food scientist and writer, author of “On Food and Cooking”

Workshop Topics

- Psychological and technical challenges of food in space (L. Chiao)
- Novel food preparation and production techniques (H. Cantu)
- Long-term and short-term hardware possibilities (D. Goldwater)
- Interactive Evolution: introduction and application to food design (Icosystem)
- Brainstorming / discussion

Space Food Issues

(adapted from L. Chiao)



The importance of space food

- Survival
  - Body mass
  - Bone strength
- Crew morale

Space Food Today

- American, Russian, European and Japanese space agencies all work on space food.
  - European and Japanese space agencies make special, ethnic foods for their astronauts
  - These foods are manifested for launch on either American or Russian vehicles, for European or Japanese missions

Space Food Today

- American Space Food
  - Extensive use of commercial Meals-Ready-to-Eat (MRE's) that are also used by the military
  - Extensive use of freeze-dried foods that are custom made
  - "Bonus" containers for long-duration flyers (commercial items that are approved by NASA food specialists)

Space Food Today

- Russian Space Food
  - Extensive use of canned items
  - Extensive use of freeze-dried items
  - All space food is custom made
  - Some commercial “bonus” items are allowed

Food and Crew Morale

- Long duration space experience parallels other long-duration activities
  - Historical sailing expeditions
  - Antarctic winter expeditions
  - Missile submarine cruises
- All long-duration crews talk about the importance of food (or lack thereof)
  - Food as a “reward” for a good day of work

Food and Crew Morale

- MIR 24 Experience
  - Late crewman substitution did not allow for food manifest substitution
    - New crewman lost approximately 30 pounds of body mass over 4 months
    - Reported significant effect on morale
- Expedition 10 Experience
  - Food shortage resulted in significant challenge to keep up crew morale

Space Food Today

- Although there is general “understanding” within NASA of the importance of food during long-duration spaceflight, only long-duration flyers that have “been there” really feel it and really understand.
- Because of the Expedition 10 experience, NASA managers are more aware of the importance of food
  - NASA is still very Shuttle-centric, but changing
  - The Russians, because of their long history of space stations, better understand the importance of food

Space Food Today

- Space food specialists have done a good job of offering menu variety, within the limitations of the hardware and other factors
- However, *besides adding a few menu items, space food has not changed much over the last 15 years*
- As we fly longer missions and branch out back to the Moon and on to Mars, food will only become more important!

Space Food Hardware Today

- No “cooking” is done onboard today’s space vehicles
- Example: Space Shuttle
  - Hydration station (hot/cool) for freeze-dried packages
  - Convective food warmer

Space Food Hardware Today

- Soyuz
  - No food warmer, no hot water
    - All food is eaten cold, no freeze-dried items
- International Space Station
  - Russian hydration station (hot/warm) with adapter for US food packages
  - Russian conductive warmer for canned food
  - US conductive food warmer for MRE's and other items

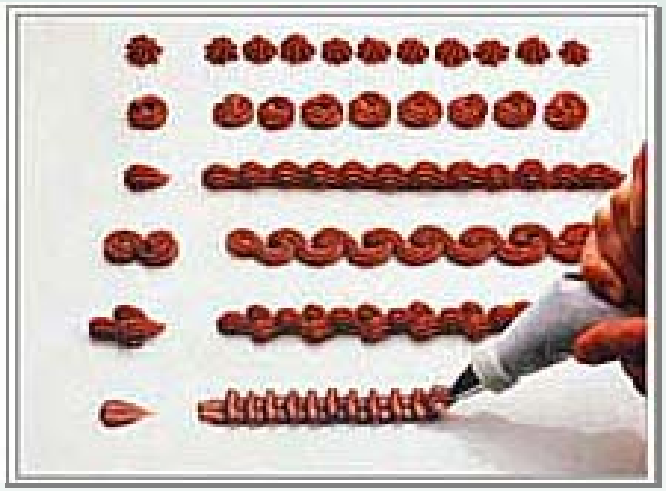
Novel Space Food Technology: Limitations

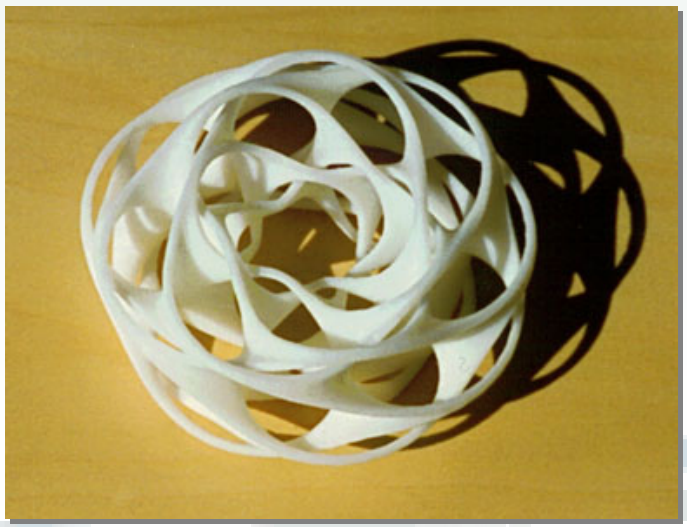
- Power consumption
- Transportability
- Temperature limitations
- Containment of materials
- Cleaning & maintenance
- Quality and variety of foods

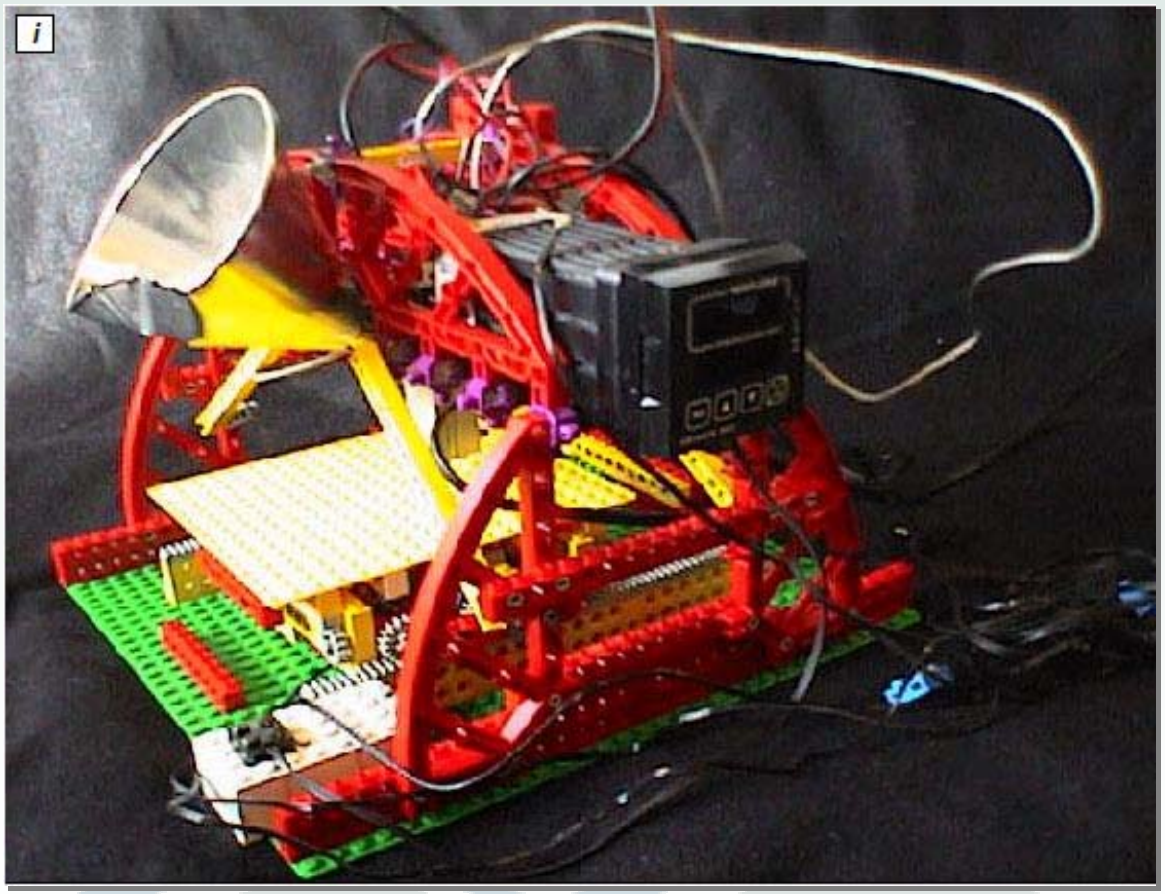
Novel (existing) technologies for food preparation

- Cantu Designs: Innovative food preparation techniques create entirely novel taste/texture combinations
  - Laser
  - Vacuum
  - Liquid Nitrogen
  - Edible paper
- Example: make popcorn by burning packaging material with laser

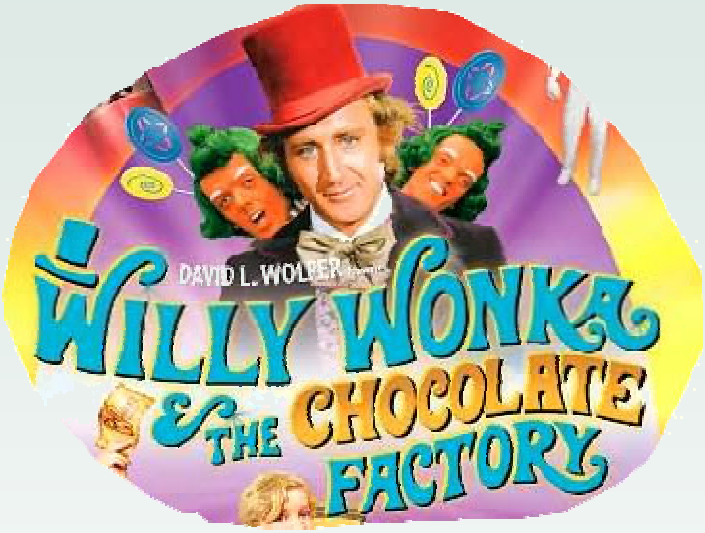
Fused Deposition Modeling (FDM)
Commercialized by Stratasys







Droplet (inkjet) printing

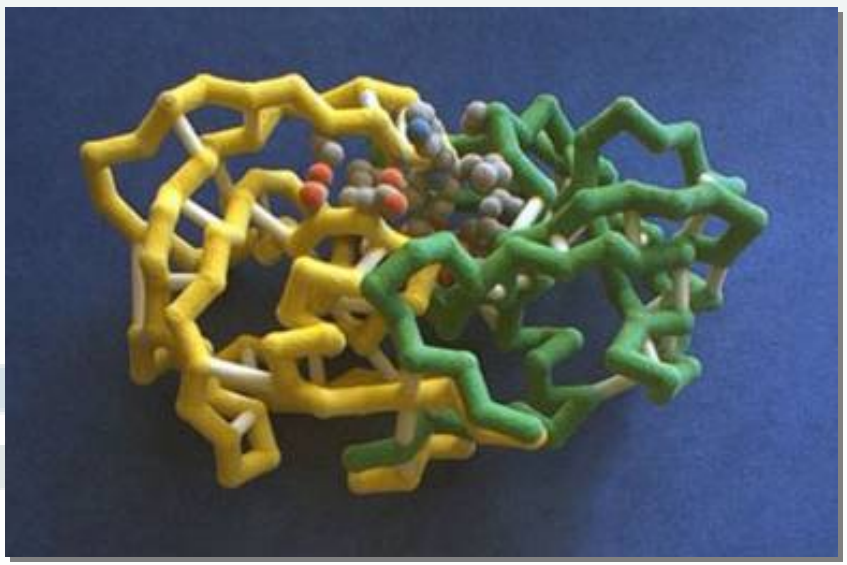


Powder + Binder 3D Printing
(commercialized by Zcorp)

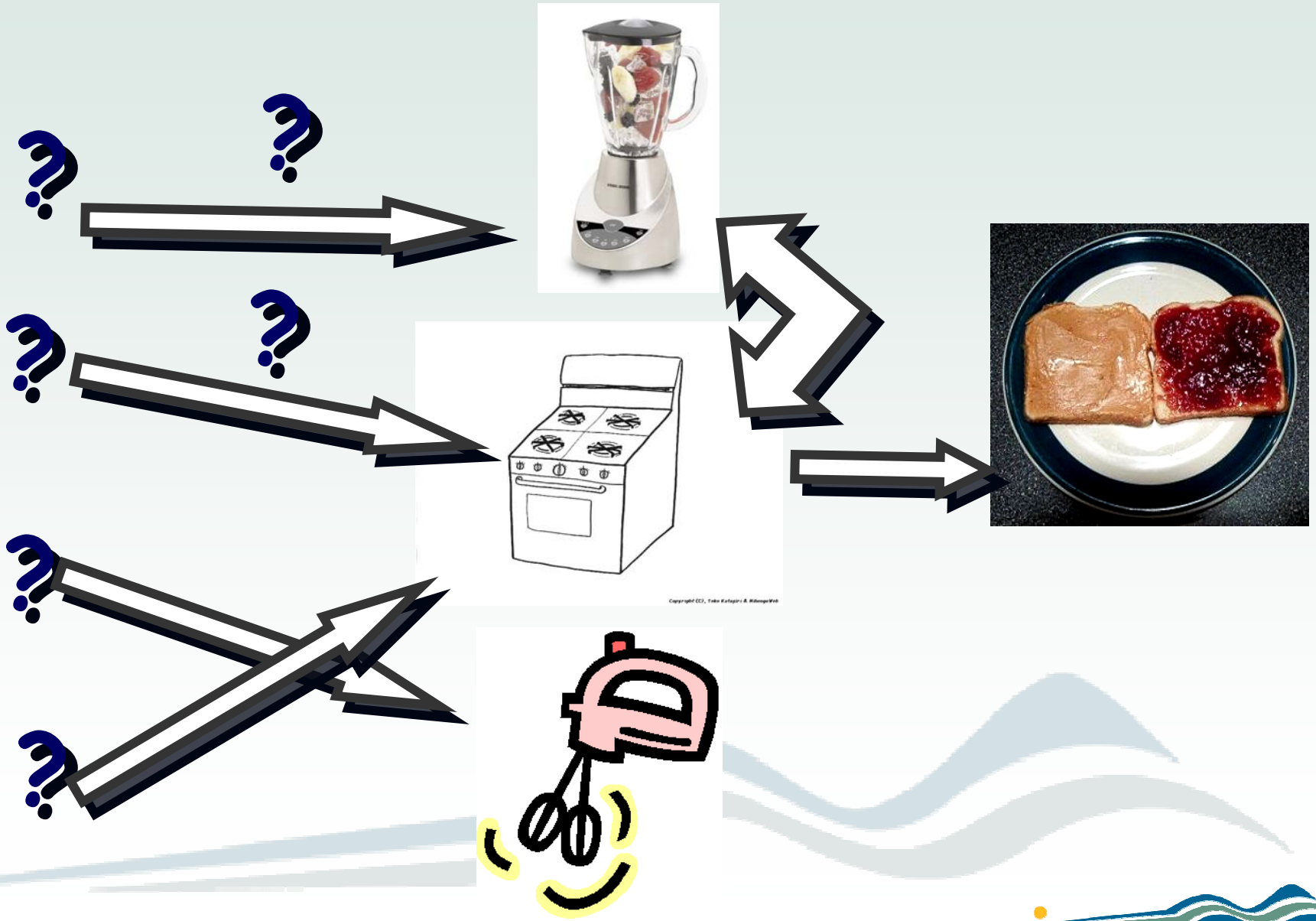
Spectrum Z™510 System

Next-Generation High-Definition Color 3D Printing System

Print high-definition 3D models at an amazing speed



Replicating a known food item



Inventing new food items

Interactive Evolution

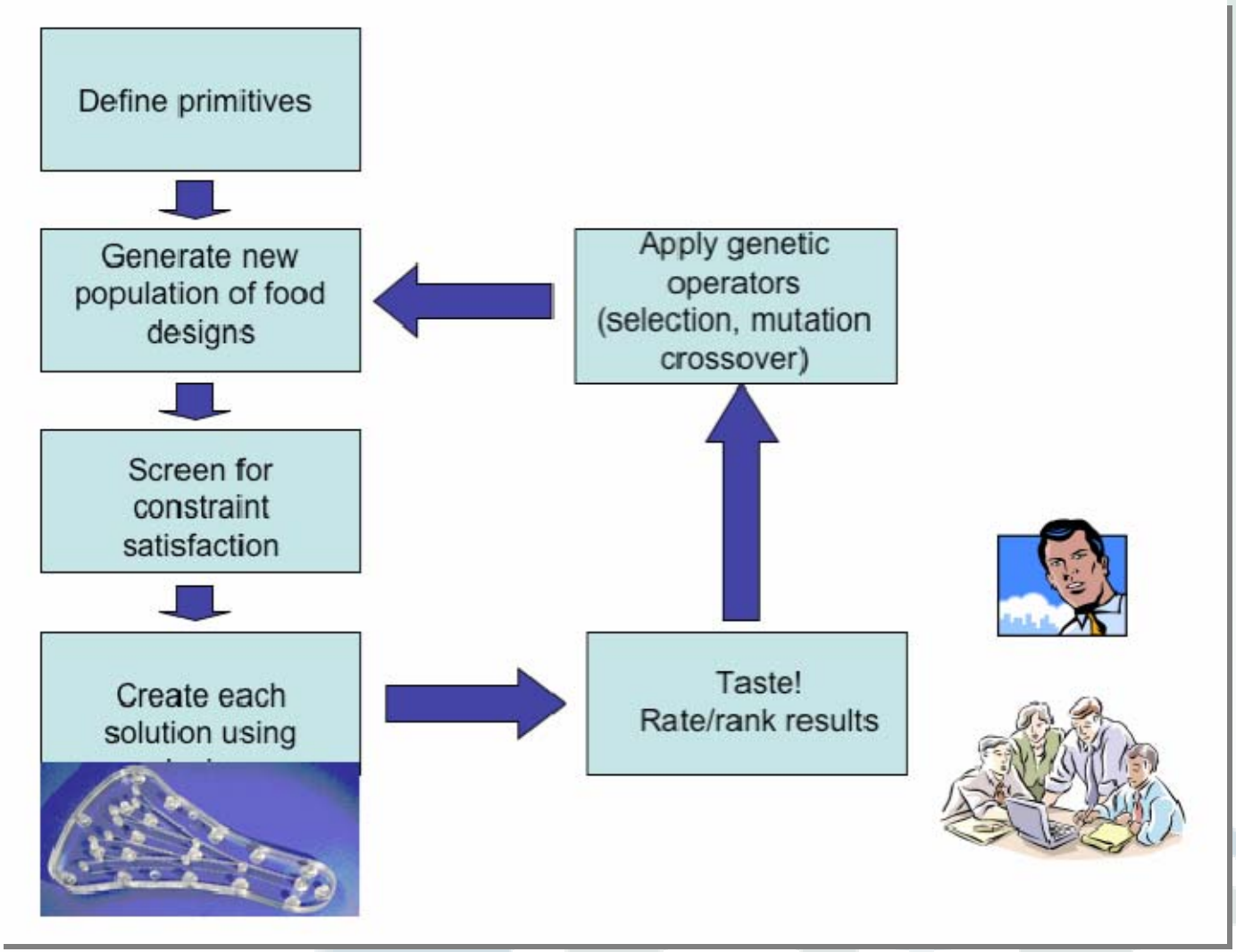
Interactive Evolution: A Brief Overview (1)

- *Evolutionary computing* - a class of search techniques inspired by biological process of evolution:
  - Individuals compete for survival
  - *Fitness function* measures performance of each individual on a desired behavior
  - Survivors reproduce through *mutation* and *crossover*

Interactive Evolution: A Brief Overview (2)

- *Interactive Evolution* - Evolutionary computing with humans providing part or all of the fitness function. Ideal when:
  - Fitness function hard to quantify
  - Highly subjective evaluation
  - Fitness changes over time
  - The “item” being sought is not known in advance

IE Process

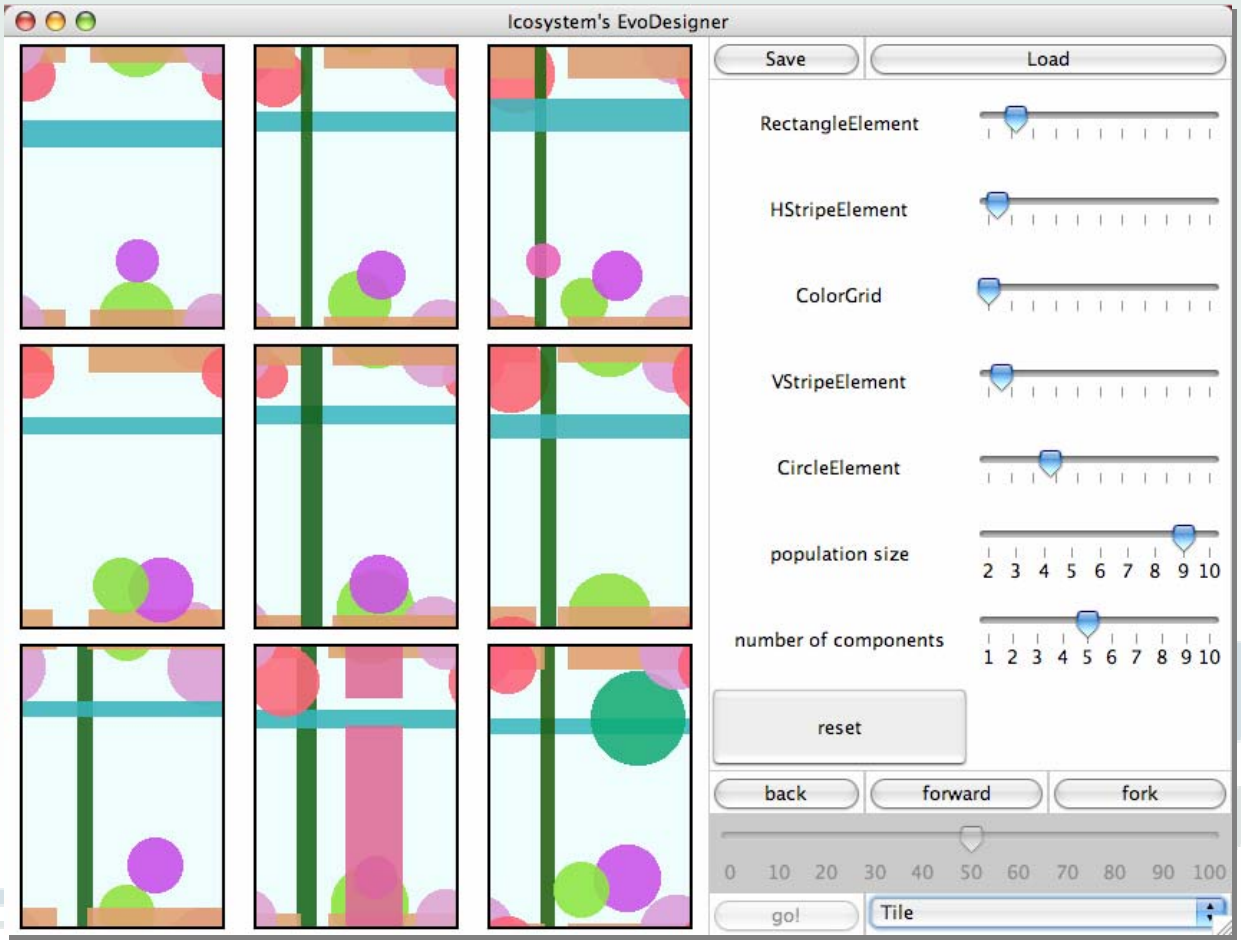

Define primitives
Generate new population of food designs
Screen for constraint satisfaction
Create each solution using
Taste! Rate/rank results
Apply genetic operators (selection, mutation crossover)

IE: internal projects

- *GiftFinder*: Explore a large catalog to find “just the right present”
- *IcoPhoto*: Apply filters to digital photos to improve image quality or artistic effects
- *EvoDesign*: Interactive design of visual patterns for tiling, fabric
- *Interactive data mining*: Search for patterns in large data sets
- *Social game*: Evolve rules for social game that generates group movement patterns
- *IcoMusic*: Guided exploration of music catalogs

Example: EvoDesign

- Create “artistic” tiling pattern using simple geometric elements



IE: Externally funded projects

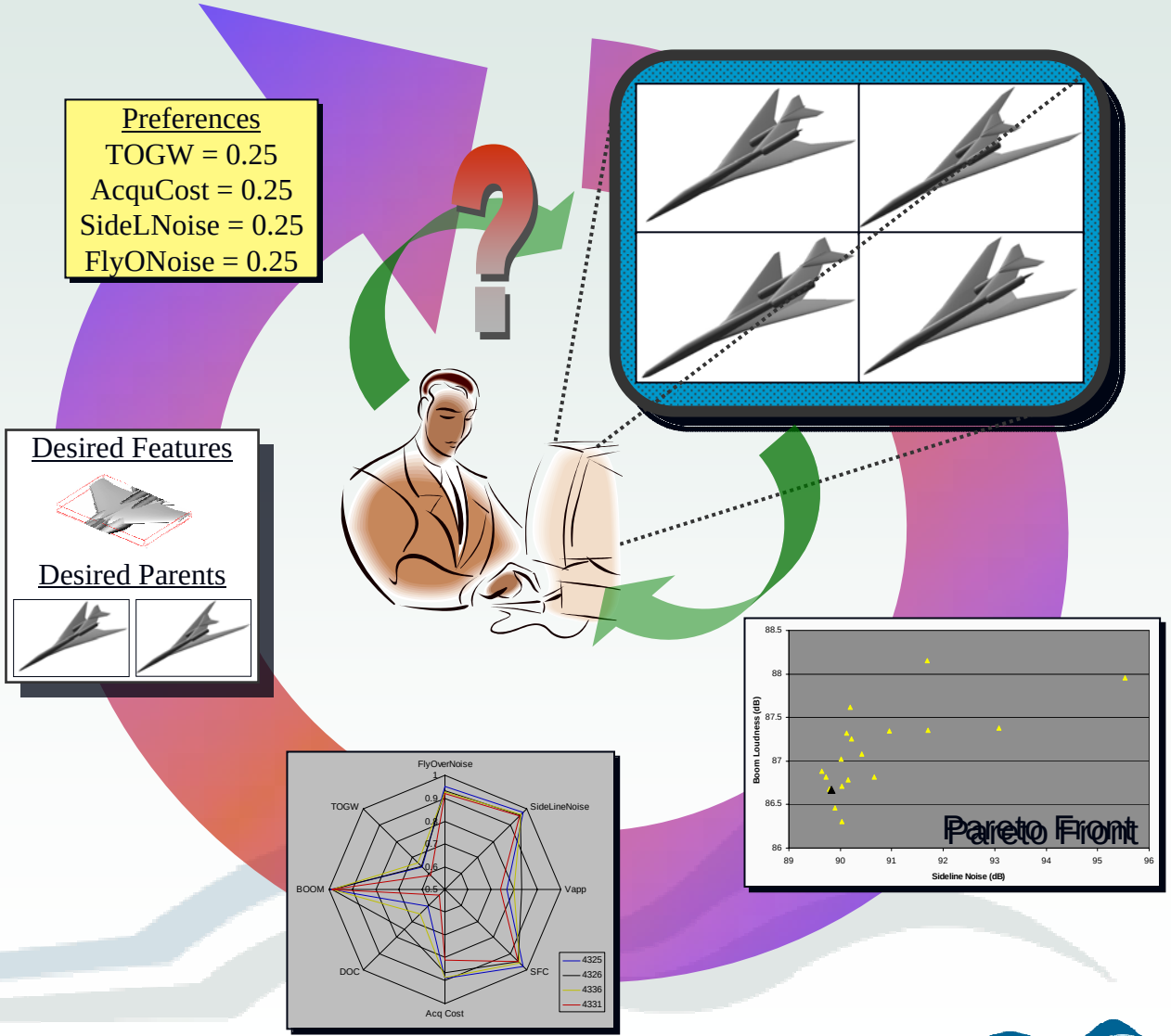
- **Design of hypersonic aircraft (U.S. Navy)**
- Search for candidate molecules in drug development (Icosystem spinoff)
- Design of “optimal” postal routes that satisfy mail carrier subjective preferences (large European postal service)
- *Text Visualization*: Guided search for mapping to capture meaning in text
- Autocalibration of complex consumer models
- Interactive design of food for astronauts

Aircraft Interactive Design

Client:
Office of Naval Research

Challenge:
Combine designer creativity and hard constraints (structural, aerodynamic, cost, …)

Approach:
Computer-assisted creative design tool for interactive search of complex design spaces



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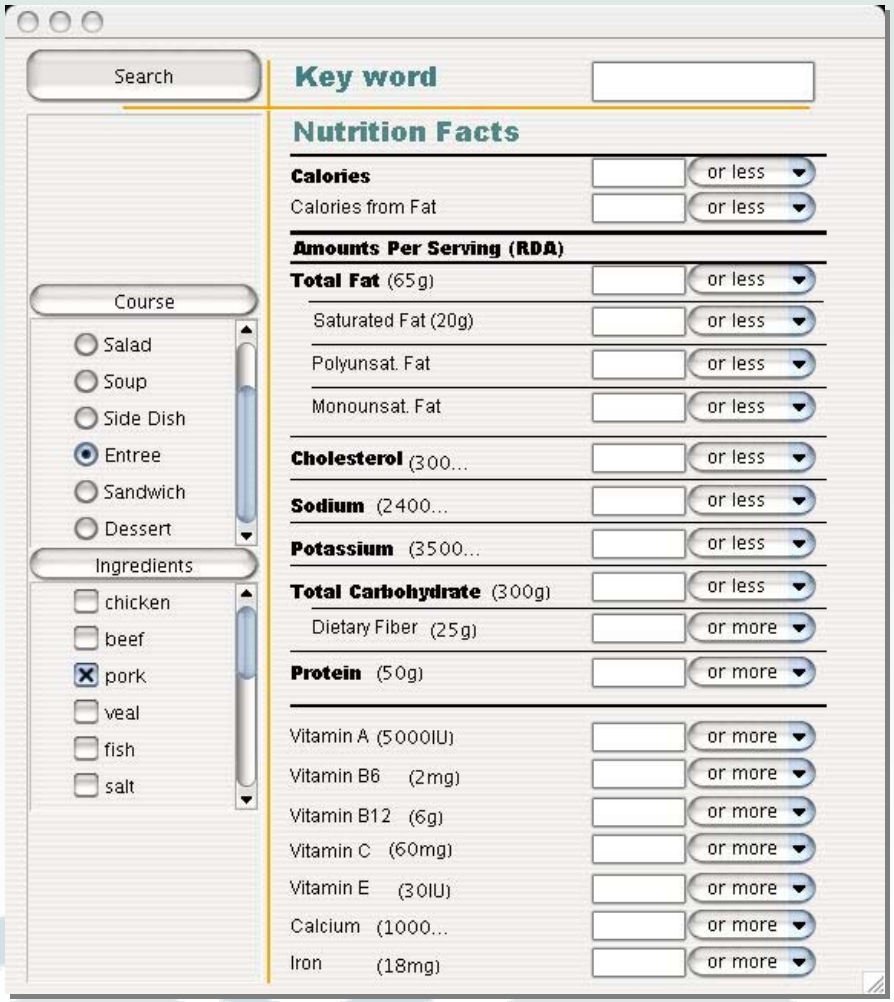
- *Text Visualization*: Guided search for mapping to capture meaning in text
- Autocalibration of complex consumer models
- **Interactive design of food for astronauts**

Proof of concept: EvoCuisine

- Search through database of recipes* based on ingredients, dish type, nutritional constraints, etc…



*We thank Larry Barcot and Kelly Burgess of *RecipeManager* for access to their database and technical support with the project.


Evolving Recipes
Save
Load
Pork Valenciana
A simplified version of the classic Spanish one-dish-meal paella. Easy enough for everyday, but impressive enough for company. Serve with sangria and hot French bread.Calories: 410
Carbohydrates: 48
Category: Entree
Protein: 25
Saturated Fat: 3
INGREDIENTS
1 1/2 Pound boneless pork loin, cut into 3/4-inch cubes
2 Tablespoon olive oil, divided
2 Medium yellow onions, peeled and chopped
1 Medium green bell pepper, seeded and chopped
2 Clove garlic, minced
1 1/2 teaspoon salt
1 Each bay leaf
8 Ounce tomatoes, undrained
1/4 Teaspoon pepper
2 Cup rice
4 Cup water
2 Each chicken bouillon cubes
1/2 Cup sherry
1/8 Teaspoon saffron threads
DIRECTIONS
Brown pork in 1 tablespoon oil over medium-high heat, remove.
Add onion, green pepper and garlic and remaining oil. Continue cooking until slightly brown, about 5 minutes. Return pork to pan and stir in salt, bay leaf, tomatoes and pepper. Add rice, water, bouillon and sherry. Dissolve saffron in small amount of water and add. Bring to boil, cover and simmer low 15 minutes.
Garnish with green peas, olives and pimientos.
TheRecipeManager
TheRecipeManager
TheRecipeManager
fork
evolve
% Xover
0
50
100
Hill-climbing

Interactive Search Issues

- User fatigue during interactive search
  - Can expect at most 4-5 rounds of user feedback
- The software must recognize promising foods without presenting each combination
- Individual astronauts have different preferences: software should adapt to different users
  - Includes implicit preferences as in the current demo: user enters chicken, but really means chicken entrée

Conclusions

The Future of Space Food

- This is the time for radical, new ideas!
- New space food hardware will enable new space food products
- Make “Earth” foods, only when a high-quality replication is possible
- Invent new foods!
  - It is better to make something new, rather than do a mediocre job of replicating something familiar

Phase II Objectives

- **Short-term**: determine what could be built with modifications/adaptations of current technologies, address key issues
- **Long-term**: determine what could be achieved in 20+ years
- **Medium-term**: determine what steps need to be taken and what technologies need to be developed to bridge the short- and long-term objectives; identify commercial applications