Outline

• Dream: To learn - from the fundamentals to the leading edge, as needed, where needed, regardless of “specialty”
• Implementation: The Digital Library metaphor
• Design-centered introduction as the portal to a discipline
• Courses & Concept Engines
• Technology in the Classroom
• Experience
• Example Application
• Future
Learn - from the fundamentals to the leading edge.

• Customer #1: GTAE alumnus, 1 year out of school, faced with new assignment. “Class notes” too far away. Textbooks sold.

• Customer #2: Alumna, 10 years out of school. Needs quick brush-up of a different discipline to lead a cross-functional team.

• Customer #3: Engineer anywhere in the world, any time, needs to look up expression or method in any other field.

• Customer #4: Executive deciding on investment in a new technology. Seeks basic understanding.

• Guided access to any technical field.

• Learner-Adaptive interfaces.

• Learner-Adaptive organization of material and resources.
The Digital Library Metaphor

- Users need basic knowledge before seeking data
- Common resource for users from many disciplines
- *The human mind is the best search engine of all!*
- Informal, intuitive, private browsing and exploration
- Access at the speed of thought
- Meeting place for learners, teachers, disciplines and knowledge

**What type of content is best to start cross-disciplinary learning?**
- Basic knowledge, methods, data and usage experience.
- Provide guidance and linkage, and leave content development to specialists

- Bottom-up approach to developing the system. Create – test – refine – expand.
Add basic course content to the strengths of the Internet:

- Present different perspectives of the same material
- "Meta-courses" – supplement classroom time
- Forum for technical discussions
- Find & use knowledge across disciplines & levels efficiently

Courses:
Basic knowledge, logical exposition

Concept Modules:
Integration and Guidance

Practice:
Utility & relevance

Research:
Advancement of knowledge
Gateway: Design-centered introduction

1. Today’s Dreams in Various Speed Ranges
2. Designing a Flight Vehicle: Route Map of Disciplines
3. Mission Specification & TakeOff Weight
4. Force Balance during flight
5. Earth’s Atmosphere
6. Aerodynamics
7. Propulsion
8. Performance
9. Stability
10. Flight Control
11. Structures and Materials
12. High Speed Flight
13. Space Flight
Approach: The Runway Across Canyons

Materials
Control
Launch Design
ECONOMICS
Relaxed Stability
Current Limits; Design Tradeoffs
Force & Moment Balance
Atmospherics
Weight Estimation
Mission Specification
TODAY’S DREAMS
TRADITIONS & EXPECTATIONS
WELCOME TO AEROSPACE ENGINEERING

HydroStatics
Aerodynamics
Mechanics
Chemistry
Energy

Math
Reason
Reading
Writing
Intuition
Moral Strengths
Physics
Chem
Learner-centered view of knowledge base
## Direct Access to the Sub-Disciplines of Aerospace Engineering

<table>
<thead>
<tr>
<th>Aerodynamics: Fluids</th>
<th>Solids</th>
<th>Mat’Ls</th>
<th>Propulsion</th>
<th>Astrodynamics</th>
<th>Flight Mechanics</th>
<th>Controls: Avionics</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Information</td>
<td>Business / Industry</td>
<td>Professional Societies</td>
<td>Technical Papers</td>
<td>Theses</td>
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<tr>
<td>Academic Courses</td>
<td>Simulations</td>
<td>Data</td>
<td>Computer Programs</td>
<td></td>
<td></td>
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</table>

**Interactive Site Map**
- Guide to Resources
- Worldwide Collections
- Tools & Data
- Basic Knowledge

**Digital Libraries**
- Standard Atmosphere
- Weather Forecast
- Fundamental Constants
- Stoichiometry

**Search Engine**
- Introduction to Aerospace Engineering
- Engineering Course Content

**Site Maps / Interfaces**
- Guide to Resources
- Worldwide Collections
- Tools & Data
- Basic Knowledge

**Aerospace Resources**
- Site Maps / Interfaces
- Guide to Resources
- Worldwide Collections
- Tools & Data
- Basic Knowledge

**Guide to Resources**
- World Collections
- Tools & Data
- Basic Knowledge

**Worldwide Collections**
- Standard Atmosphere
- Weather Forecast
- Fundamental Constants
- Stoichiometry

**Tools & Data**
- Introduction to Aerospace Engineering
- Engineering Course Content

**Basic Knowledge**
- Site Maps / Interfaces
- Guide to Resources
- Worldwide Collections
- Tools & Data
# Other Disciplines

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Civil</th>
<th>Materials</th>
<th>Textile</th>
<th>Mechanical</th>
<th>Bio</th>
<th>Computer</th>
<th>Electrical</th>
<th>Ind.&amp;Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>Chemistry</td>
<td>Life Sciences</td>
<td>Mathematics</td>
<td>Earth Science</td>
<td>Cognitive Science</td>
<td>Business / Management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Image of a lunar rover]
Technology in Learning

- Spaced repetition (iteration) enhances long-term memory
- Collaborative problem solving
- Learning in team environments
- Polycontextuality
- Boundary crossing
- Horizontal & vertical integration

**Observations on GT engg. students:**

- Want fast-loading pages
- Used to textbooks & equation-filled boards.
- Demand depth
- Technology usage in the classroom must be carefully limited
Reality Check for Course Redesign

Must be sure to understand good points of current system before proceeding to change it.

- Employers value rigorous curriculum, tenacity, teamwork and flexibility.
- Alumni show an excellent record of success through evolving career paths.
- Neither alumni nor employers really object to “Darwinian” systems – “Is it as tough as the education I got?”

Can the aerospace engineer who is taught using “advanced technology” compete with the one who learned through the “old, unkind” system?

- “Average” performance better at mastering content?
- “Top-performer” better?
- Should the measurement criteria be changed from “content mastery”?
- Does the “real world” REALLY accept such changes?
- “Survival skills” of past generations must not be lost by new systems
- As old problems are solved, new and more useful challenges must be introduced
Experience with ADL

*Five years of Georgia Tech Aerospace Engineering classroom usage*
– as users, resources & expectations evolved.

- 1st yr, undergrads: Average SATs ~ 1400, some with 1600
- High school GPA >3.5. 40% cite Space career motivation
- Sophomore through senior classes include roughly 50% with some “work” experience - Co-ops, internships, assistantships
- Graduate students from schools worldwide
- Approx. 400 users of ADL so far in *formal courses*.
- Courses & learners at all levels – Freshman through PhD. Theory, experiment, projects and competition teams.

*Usage in courses*
- Lower-division classes use ‘net through cross-linked web-based notes and assignments requiring web searches – to take independent decisions
- Upper-division courses expect web usage to find published data and methods
- Graduate courses use web in finding and correlating with published research
Students use ADL in many ways

- Project teams use the site for “Knowledge Management”.
- Links to digital libraries and NASA resources.
- Discussions with faculty across the world.
- 50% of students in courses using ADL go directly to ADL link; other 50% will go to traditional paper sources first.

- Perception of deeper learning with web-based ADL material - reinforces lectures, provides different perspectives

- **Freshman course - students learn to cross disciplines easily part of conceptual design process.**

- “Lab” courses, design & independent projects provide cross-discipline experience.

- Transfer from research to undergrad courses working well.

- Reverse process may also be working -

- Heavy usage as part of the courses; yet over 70% of total usage came from outside GT; 18% usage from outside the US.
Learning on the Net

- Where are they learning?
  - 60% of their learning was from attending class
  - 10-15% from the web-based notes
  - 10-15% from out-of-class discussions (emails, forums)
  - 10% from independent exploration (Internet and paper-based)
  - 5% from the textbook.

- Why web-based notes?
  - “reference” about what they wrote down in class
  - clarifications on assignment
  - iterating between sources to study for tests
  - links to other web resources
  - learn better than is possible from the sequential “absolute” presentation in textbooks
Concept Module Presentation

• Strong positive response at all levels for Concept Modules
  - Material presented in concise segments
• Classroom presentation and Concept Engines were presented in two styles for upper-level students:
  – Traditional classroom lectures with shorter web notes
  – Longer, more detailed web notes assigned as homework reading with lectures only to answer questions.

• 1/3 of the students liked traditional lectures with shorter web notes, 1/3 liked detailed web notes as assigned reading, with lectures for question sessions. The rest were neutral.

• Majority did not read ahead of the lectures, some said that “seemed to be a good idea for the future”.

• For independent-thinking assignments - 50% utilized the web-based information first, other 50% went straight to the traditional library.
Observations

• Comfort level not yet adequate to make digital resource the primary means of learning – a necessary step for routine cross-disciplinary learning

• Students gravitate to the “lighter” presentations

• Many students print web site content like class notes

• Some learners feel overwhelmed by the Internet, and by the challenge of prioritizing information

• Surprisingly few cite difficulties with nomenclature and terminology

• In no case has the availability of digital resources reduced in-class attendance

• In fact, human interaction and guidance are appreciated more emphatically
Crossing Discipline Boundaries

• Preference for a familiar interface: Learner-centered nodes are needed in each discipline, cross-linked to facilitate access.

• Learner preferences vary greatly even between classmates – need multiple structures for the links to the material.

• Given an essential core of in-depth material and broad concept explanations, users are happy to do their own searches.

• Local storage unnecessary - cross-disciplinary resources are linked
  - encouraging finding on how people prefer to learn across disciplines.
## Learning Styles

<table>
<thead>
<tr>
<th>Kolb Learning Style</th>
<th>Description</th>
</tr>
</thead>
</table>
| Accommodators       | • Prefer concrete experience and active experimentation  
                      | • Prefer accurate organized delivery of material  
                      | • Respectful of the “expert”  
                      | • Like to know the “right” answer to the problem without experimentation |
| Assimilators        |             |
| Convergers          | • Like to understand the relevancy of problem (how it works)  
                      | • Prefers detailed information on operation  
                      | • Like to understand why something works  
                      | • Prefers to explore  
                      | • Likes information to be detailed, systematic and reasoned |
| Divergers           |             |
## Interfaces to Suit Learner Types

<table>
<thead>
<tr>
<th>Interface</th>
<th>Astronaut</th>
<th>Eagle</th>
<th>Barnstormer</th>
<th>Rocket Scientist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner Style</td>
<td>Sensory/ sequential</td>
<td>Global / Intuitive</td>
<td>Global / sensory</td>
<td>Intuitive</td>
</tr>
<tr>
<td>Emphasis /</td>
<td>Sequential Inductive</td>
<td>Site-maps -free to</td>
<td>Perspective. Theory linked:</td>
<td>Theory. Hyperlinked</td>
</tr>
<tr>
<td>Presentation</td>
<td>organization.</td>
<td>pick precise items quickly</td>
<td>problem-based approach.</td>
<td>derivations; use of</td>
</tr>
<tr>
<td>Reasoning</td>
<td>Inductive / Active</td>
<td>Inductive / deductive</td>
<td>Inductive/ deductive</td>
<td>mathematics.</td>
</tr>
<tr>
<td>Resource Types</td>
<td>Modules Point summaries</td>
<td>Database subject; glossaries;</td>
<td>Concept Engines, Data</td>
<td>Theorems; proofs. Logic,</td>
</tr>
<tr>
<td></td>
<td>Re-iteration Examples</td>
<td>Insight Hyperbolic Tree;</td>
<td>Graphics. Examples,</td>
<td>Original papers. Concept</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Site Maps, charts.</td>
<td>Calculators</td>
<td>Engines. History.</td>
</tr>
<tr>
<td>Inp. emphasis</td>
<td>Auditory</td>
<td>Visual</td>
<td>Kinesthetic</td>
<td>Auditory</td>
</tr>
</tbody>
</table>
Other Reactions

Engg. Alumni: positive and comfortable with ADL resources, cite desktop, on-demand access to course notes.

Contribute items for informal publication, urging usage in classes.

Other professionals: Usage not yet known to be significant. The idea of being able to find reliable in-depth resources and guidance on the web is new.

Other faculty: Dichotomy between those who appreciate, and others who reject, the necessity of teaching to solve problems across disciplines.
Steady-State Self-Sustainment

5th year of existence

• Moderate but useful level of existence and growth.
• Local storage is under 2 GB - a small fraction of the linked resources.
• Design-centered interface is heavily used, as is the undergraduate course content.
• Not practical to limit usage to “peer-reviewed” resources.
• Developing traits for independent validation of data appears to be most practical course at this time.
• Suggests need and role for different system of “peer reviewed Publication” where validity is established by open discussion and presentation of alternatives.

Unique Users Per Month
Example Application

- Collection of Space Business resources, linked to technology and costing, for future entrepreneurs.

Space Based Economy

Self-sustaining Economy

Support/Service Economy

- Com-sats
- Space Station
- Robotics
- Fuel
- Repair
- Research
- Exploration
- Military
- Sensing
- GPS
- Maintenance
- Lunar Resources
- Lunar Power
- Lunar Manufacturing
- Lunar Launcher
- Space Habitats
- E.T. Manufacturing
- Orbit transfer vehicles
- GEO/ L1 Station
- Earth Launch
There’s Space in Your Future
Future Directions

- Shift focus from resource acquisition to refinement of content, cross-linking and error elimination
- Publication system for original work in a cross-disciplinary problem-solving context
- Extensive indexing and cross-linking system using Concept Engines to enable users from distant fields to find each other through research motivated from entirely different viewpoints
- Meaningful Interactivity - Java applets and database access
- Metaphor shift from “digital library” to “active engineering environment” suggested by usage patterns (“Library” is no longer a familiar term)
- The dream of the Modern Engineer, in an environment where all the data and calculation methods that one ever wants are accessible at the speed of thought, is beginning to look feasible.
Summary

Learner-centered resource for learning engineering fundamentals and solving problems across levels and disciplines. Specific objectives were:

• Develop core of fundamental knowledge on several disciplines accessible through the Internet, sufficient to form a useful learning resource for various levels.

• Develop user experience in courses and research programs as a learning resource.

• Assess learning methods and curricular structures enabled by these resources.

• Test hypotheses about self-sustainment, growth and self-organization.

First phase of the development - demonstrated self-sustainment and moderate growth in content and relevance to learners worldwide.
Summary: What is Enabled Today

• First semester students do a credible job of “conceptual design”, integrating data and experience from all over the world. Replaces “overview” course

• “Design” type large-system assignments with realistic parameters at all levels

• Web-based reporting of assignments – iteration for improvement

• Better vertical and horizontal integration – helps perspective at all levels

• Communicates “expectations”, enhancing open-ended assgts (“The WORD”)

• Courses improve with every teaching – “prior work” is online!

• “24x7” access to course notes, examples and references at every level

• Size of resource now large enough to accommodate different learner styles

• Usage by non-GTAE students now far exceeds captive audience usage – opportunity for use as a publication medium

• Routine usage (e.g. of NASA TRs, TMs) in courses AND research through ADL

• Absent-minded profs can forget their notes and not panic – can also tailor what students see & use for each assignment with “FAQs”

• Growth of interesting sites and data found by students and alumni

• NO dilution of the standards of thinking needed on tests and assgts
Conclusions

Most sought by users across disciplines: *basic-level course notes*

Value in guided access to application data and results, and thence to sources of advanced knowledge.

Linked resources developed from course notes are seen to be valuable, when accompanied by clear explanations of concepts.

The idea of a discipline-specific portal providing access to the rest of the knowledge base has been demonstrated.

– and is ready for emulation in other disciplines to form a true cross-disciplinary worldwide engineering environment.

Acknowledgements

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