Idaho National Engineering and Environmental Laboratory

Systems Analysis

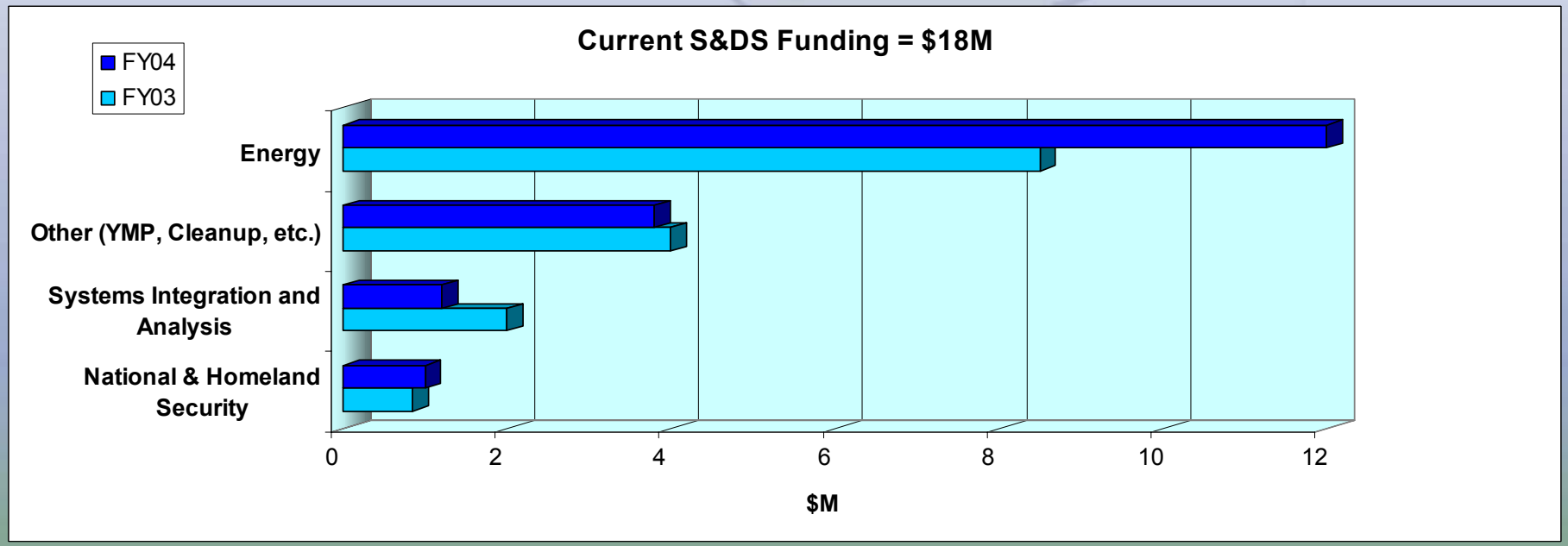
Finis Southworth, PhD
Department Manager Systems & Decision Science

DOE Hydrogen, Fuel Cells, and Infrastructure Technologies Program
Systems Analysis Workshop
July 28-29, 2004
Washington, D.C.

Charter

Systems & Decision Science Mission: Develop and apply science-based systems, systems engineering, and decision science capabilities that result in successful projects and effective, defensible decisions

Systems & Decision Science Funding:



History

The S&DS group has been performing detailed systems analysis since 1993

Examples Include:

- New Production Reactor (1989-1993)
- Air Support Operations Center (1995)
- Long-term Stewardship Science and Technology Roadmap (2002)
  Remote Standoff Explosive Detection System (2003)
- Nuclear Hydrogen Initiative R&D Plan (2003)
- Advanced Fuel Cycle Repository Futures Analysis (2004)
- Future Combat System of Systems Integration (2004)
- NGNP Independent Technology Review (2004)
- Pine Bluff Mobile Munitions Assessment System (2004)
- Yucca Mountain Requirements Management (2004)
- Yucca Mountain System Design Description (2004)

Skill Set – People

Systems & Decision Science Department

Finis Southworth, Manager
Cheryl Noble, Department Support

Decision Support
Bob Caliva, Group Lead

- Lori Braase
- Jennifer Cameron
- Alison Conner
- Brent Dixon
- Clint Graden
- Doug Hamelin
- Darcie Martinson
- James Murphy
- Kyle Oswald
- Bryan Parker
- Marty Plum
- Karen Scott
- Linda Seward
- Bob Turk
- Buck West

Project Support

- Bob Korenke
- Sam Alessi
- John Cox
- Ed Gorski
- Dennis Harrell
- George Hayner
- Burton Koske (DC)
- Dana Meyer
- Cathy Plowman

Systems Support
Ron Klingler, Group Lead

- Ron Barden
- Brion Bennett
- James Case
- Norm Cole
- Ramona Dunihoo
- Brad Gardner
- Donna Guillen
- Harold Heydt
- Mindy Kirkpatrick
- Ed Lee
- Patricia McGrath
- Ray McKenzie
- Bruce Nielson
- Charles Park
- Tracy Ricks
- Rafael Soto
- Mike Walrath
- Scott Wold
- Rob Zamecnik
- Larry Zirker

Total Personnel As Of 06/28/04 – 48

Skill Set – Models

Hydrogen Related Models

- ***High Temperature Electrolysis Hydrogen Production Parameters***
  - Excel spreadsheet to develop a self-consistent set of plant parameters for a High Temperature Electrolysis plant powered by a high temperature gas reactor. Model still under development, internal review completed.

Models Adaptable to Hydrogen

- ***APSEN - Aspen Engineering Suite (AES***
  - Chemical engineering mass balance program to determine overall plant parameters which includes equilibrium for all unit operations. Commercial software from Aspentech. No limitations.

- ***SAPHIRE (Systems Analysis Programs for Hands-on Integrated Reliability Evaluations)***
  - Probabilistic Risk Assessment to determine safety risk, reliability, life-cycle cost/risk. Limited by resources to identify lowest level of cause and effect and disk space on large analyses.

- ***RELAP5-3D***
  - General-purpose system analysis code for thermal hydraulic analyses. Originally developed for light water reactors analyses, but can analyze a variety of complex systems with different fluids and materials. Does not include chemical reactions and currently limited by those fluid properties in code, but other fluids can be added.

Skill Set – Capabilities Summary

TYPE OF ANALYSIS	RESIDENT CAPABILITY?	STUDIES SPECIFIC TO H_2?	MODELS SPECIFIC TO H_2?
Resource Analysis	Yes		
Technoeconomic Analysis	Yes	Yes NHI R&D Plan, GIF VHTR R&R Plan	
Environmental Analysis	Yes		
Delivery Analysis	Yes	Yes Phoenix, AZ Hydrogen Fueling Station Parameters	
Infrastructure Development Analysis	Yes	Yes Navy Diesel H2 Reformer Optimization, NGNP H2 Pilot Plant Requirements	Yes HTE Process Parameters,
Energy Market Analysis	Yes	Yes Propane and Natural Gas Transportation	

Studies

Past H2 Studies

- NHI R&D Plan
- NGNP Pilot Plant Infrastructure Needs
- GenIV International Forum Very High Temperature Reactor R&D Plan (including H2)

Planned H2 Studies

- Identify key technical Issues for reactor heat transfer loop (2004)
- Assess reactor interface requirements (2004)
- Assess code and standard impacts on co-siteing hydrogen production and nuclear reactor (2005)
- Analysis of material compatibility for high-temperature heat exchangers (2005)

Future

The INEEL has the primary role of integrating advanced hydrogen production capability with a high-temperature gas-cooled reactor. This demonstration is essential to increase U.S. energy independence, enhance environmental quality, and provide affordable energy.

S&DS will continue to play a central role in nuclear/ hydrogen systems integration. Contributions include: decision analysis, systems engineering, systems analysis, systems integration, and systems science products and expertise resulting in project success.

Analysis Issues

- Tendency to assume that a detailed analyses of parts of the system is sufficient. Systems Integration is needed to understand, make decisions about, and optimize the overall system of systems

- Lack of access to and the validation of information from a multitude of organizations (national laboratories, industry, government, academia, and international participants)

Backup Slides

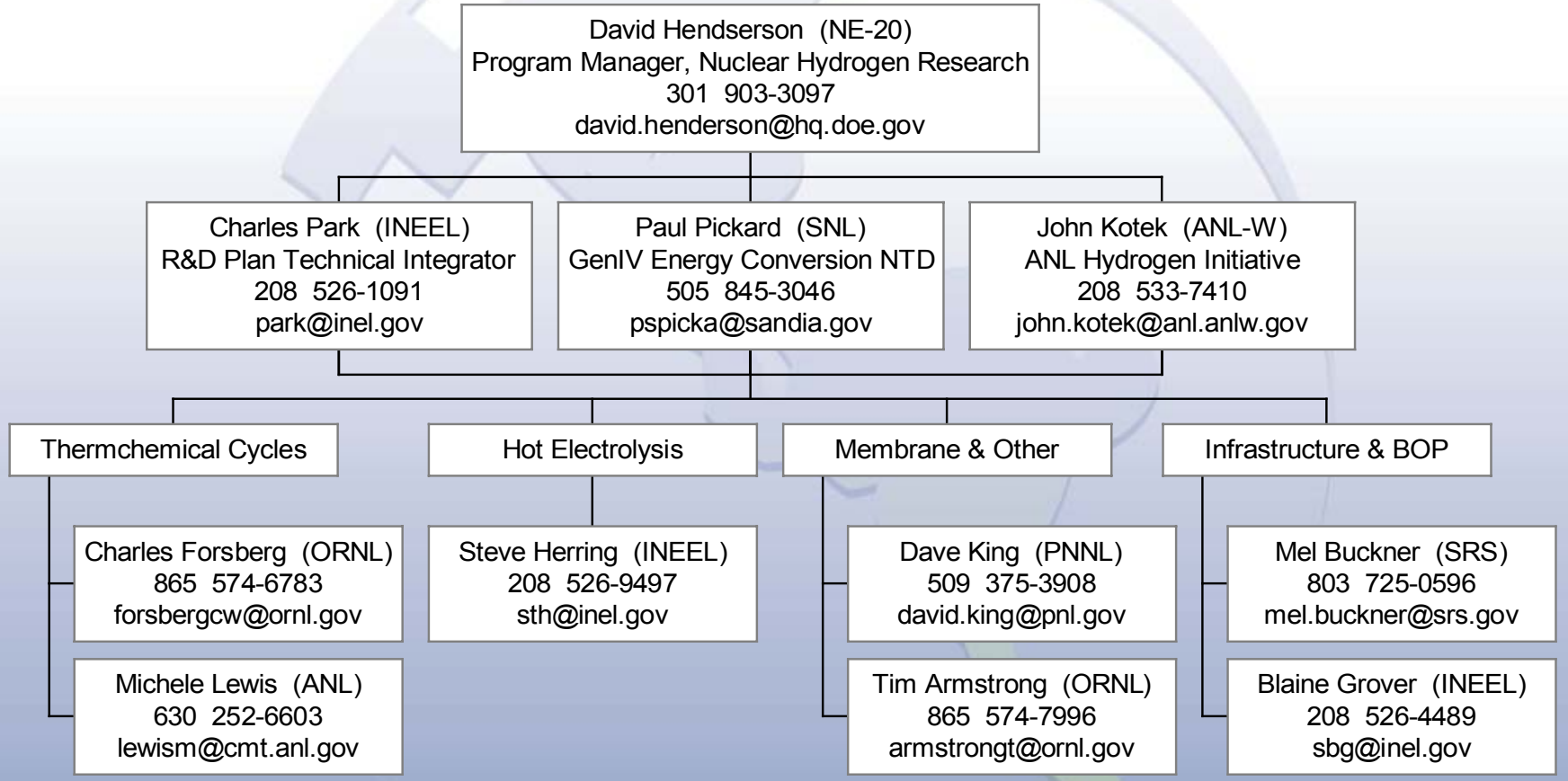
Backup Slides

Nuclear Hydrogen R&D Plan

June 13, 2003

John Kotek -- ANL
Charles Park -- INEEL
David Henderson – DOE-NE
Paul Pickard -- SNL

Nuclear Hydrogen Production R&D Plan - Participants



Nuclear Hydrogen R&D Plan

R&D Plan Outline

1. **Goals and Objectives**
   - Nuclear hydrogen role, potential benefits
   - Cost effective (< conventional electrolysis), GHG free H2
2. **R&D Plan Approach**
   - Scope, schedule, economic context / metrics
   - Gen IV heat source, not fossil based
3. **Description of Candidate Hydrogen Production Cycles**
   - Process, Status, Issues, benefits, R&D needed, priority
   - Thermochemical, electrolysis, alternative, barrier
   - IHX, balance of plant R&D needs
4. **Nuclear Hydrogen R&D Plan**
   - Baseline (TC, HTE) development plan, priorities, decision points
   - Advanced/Alternative options, R&D to support go or no-go decision
   - IHX design, materials needs to support process development
5. **Demonstration approach**
   - Scaling issues, criteria / goals, decision points

Nuclear Hydrogen R&D Plan

R&D Plan Development Stages

Options – Technical Leads

- Consider sufficient range of options to assure promising approaches have been considered.
- Define advantages, issues, status, and R&D needed
- Include thermochemical, electrolysis, barrier, alternative processes, balance of plant issues

Prioritization – Tech Leads & Integration Team

Criteria include:

- Advantages (efficiency, simplicity, costs, projected economics, ..)
- Technical difficulty (temp, materials, rx's, probability of success…)
- Technical maturity, related R&D, ready by 2015, ..)

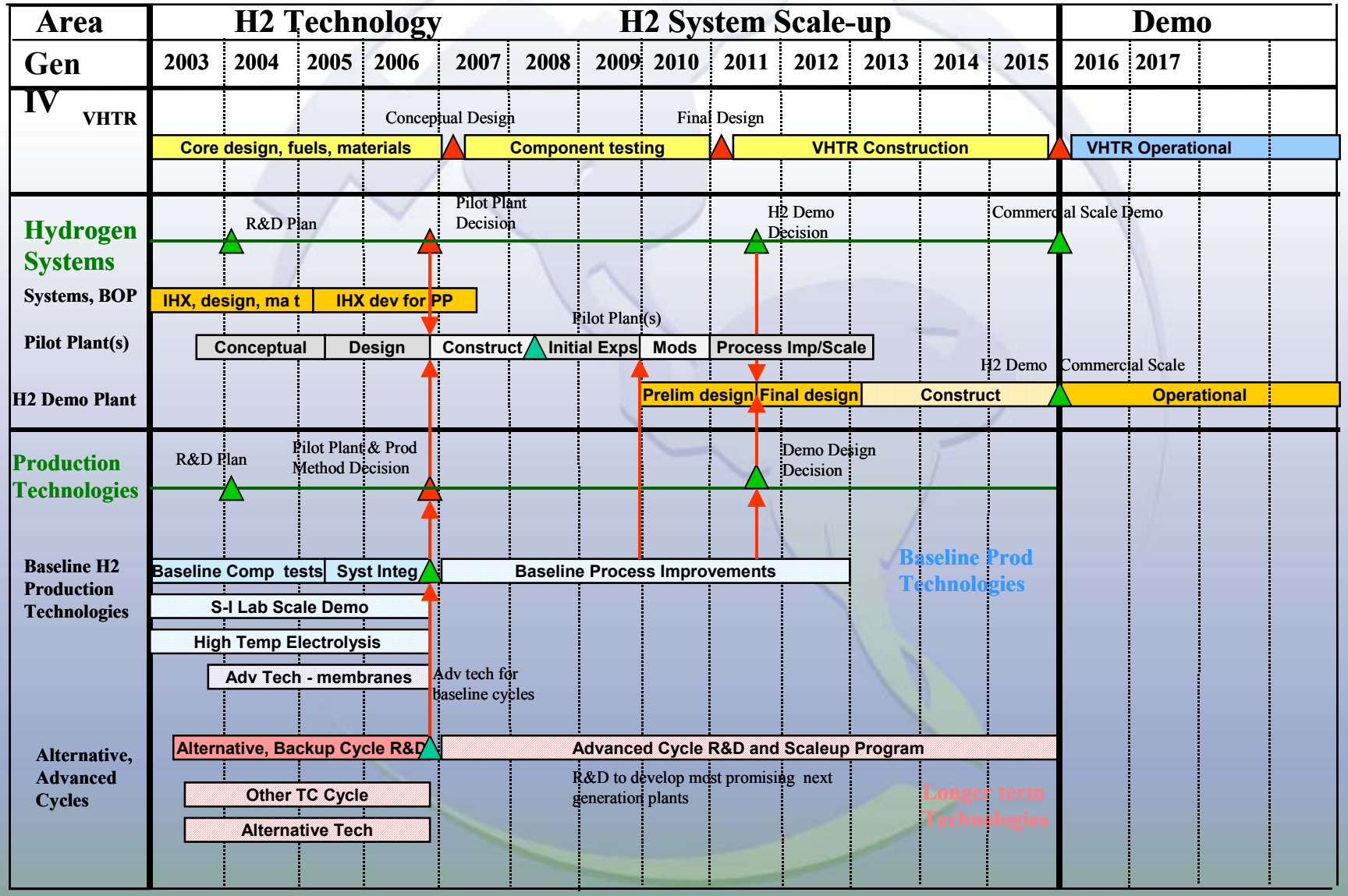
Develop R&D plans for evaluated set of production options (TC,HTE, alternatives, associated BOP)

Promising longer term options would be identified -- but not as current R&D priorities

R&D Plan – Integration team (Tech Leads, DOE)

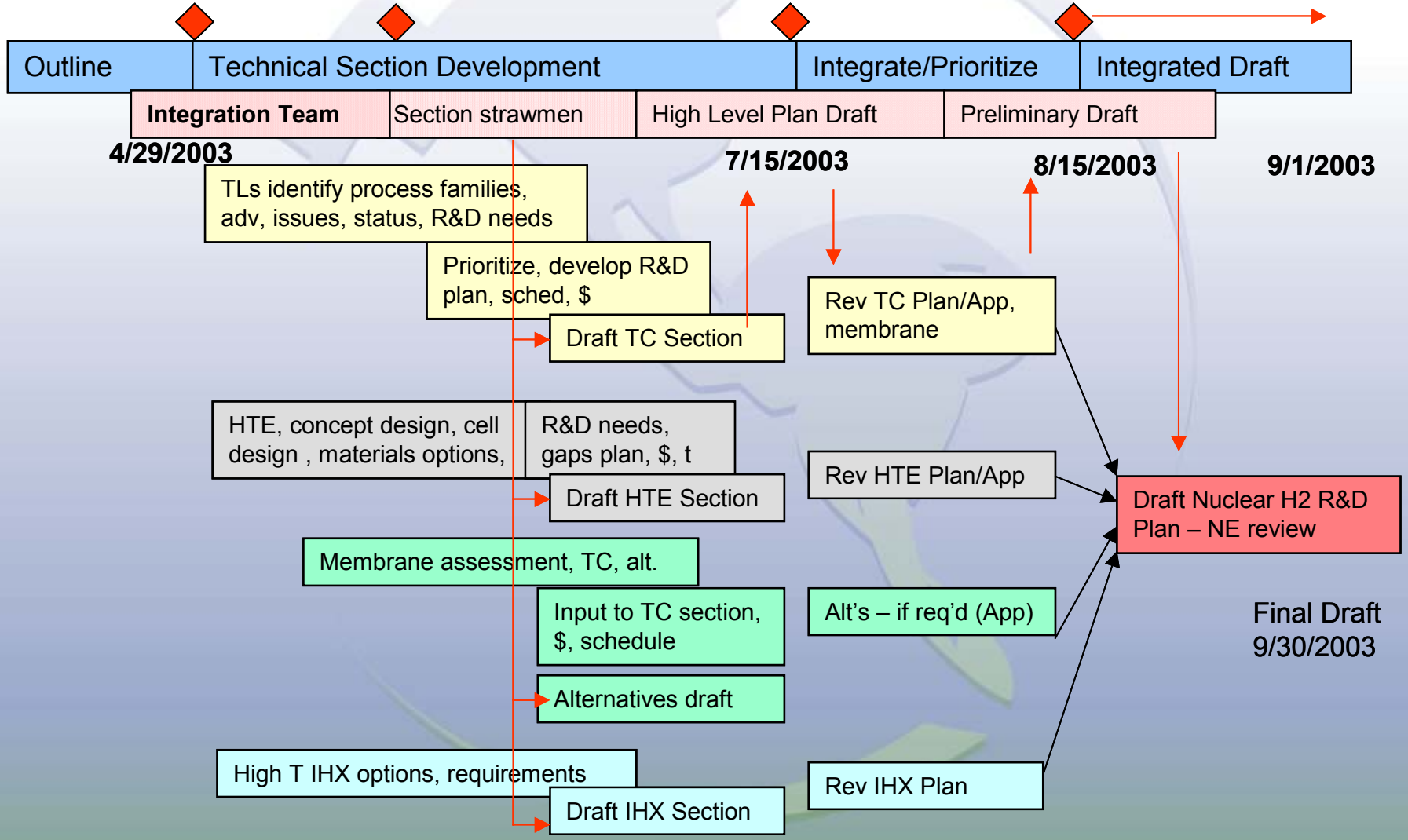
- Establish critical decisions and down select process/milestones
- Define R&D sequence for highest priority technologies
- Develop integrated budget, schedules,

Generation IV Hydrogen R&D Plan - Major Milestones



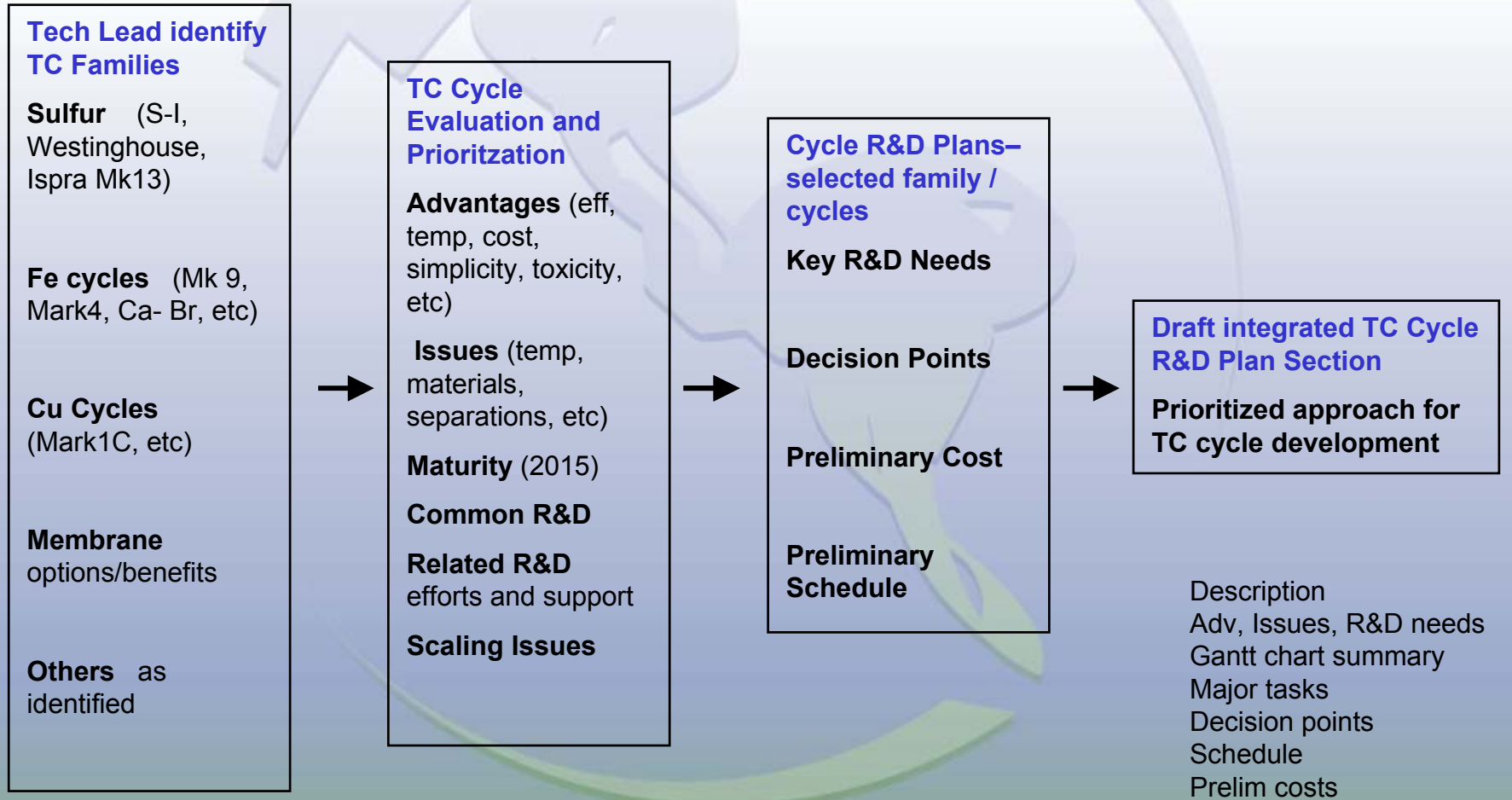
Draft

Schedule


Outline
Technical Section Development
Integrate/Prioritize
Integrated Draft
Integration Team
Section strawmen
High Level Plan Draft
Preliminary Draft
4/29/2003
7/15/2003
8/15/2003
9/1/2003
TLs identify process families, adv, issues, status, R&D needs
Prioritize, develop R&D plan, sched, $
Draft TC Section
Rev TC Plan/App, membrane
HTE, concept design, cell design , materials options,
R&D needs, gaps plan, $, t
Draft HTE Section
Rev HTE Plan/App
Draft Nuclear H2 R&D Plan – NE review
Membrane assessment, TC, alt.
Input to TC section, $, schedule
Alt's – if req'd (App)
Final Draft 9/30/2003
Alternatives draft
High T IHX options, requirements
Draft IHX Section
Rev IHX Plan

Nuclear Hydrogen R&D Plan

Thermochemical Cycle R&D Plan Process

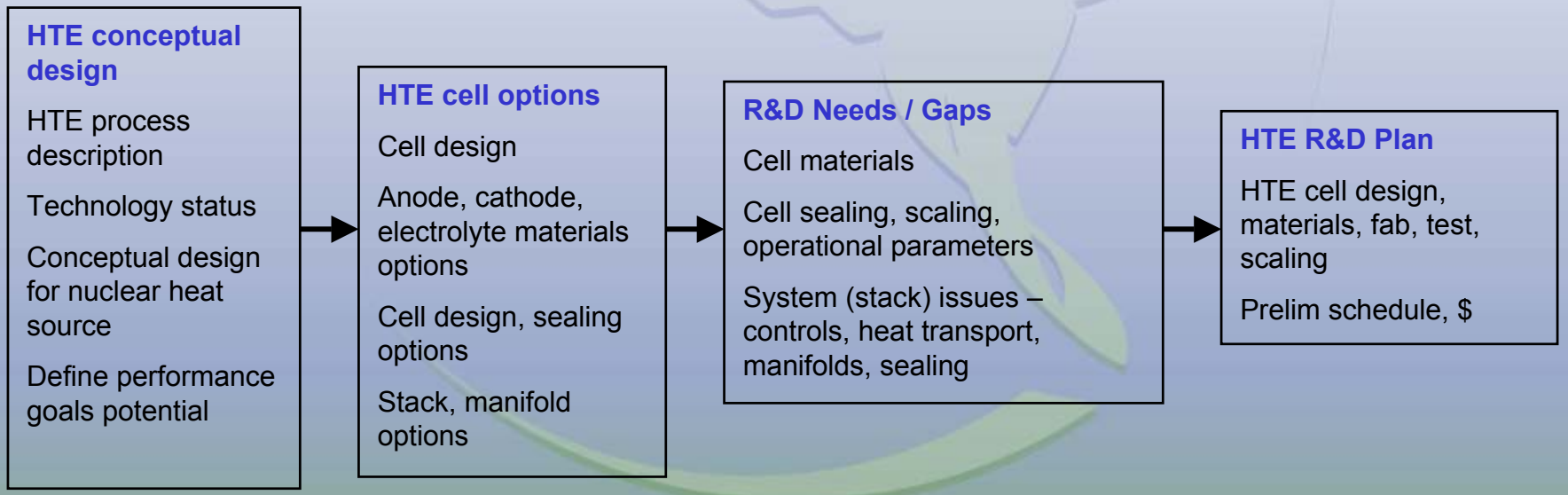


Nuclear Hydrogen R&D Plan

High Temperature Electrolysis R&D Plan

Major HTE R&D Plan Elements

1. Conceptual designs for HTEx system, performance potential
2. Identify cell options, materials, technology status, current R&D
3. Develop R&D plan, cell development, scaling demonstration



Nuclear Hydrogen R&D Plan

High Temperature IHX, BOP R&D Issues

Major IHX R&D Plan Elements

1. **Define interface requirements from TC, HTE, Alternative cycles**
2. **Identify IHX design and materials options**
3. **Develop R&D plan for IHX materials, designs, testing**

IHX/BOP R&D based on H2 process requirements, focus, integrate UNLV effort