ADVANCED REACTOR, FUEL CYCLE, AND ENERGY PRODUCTS WORKSHOP FOR UNIVERSITIES

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Separations

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Workshop for Universities
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Program Elements

- Advanced aqueous separations
- Pyrochemical separations
- Engineered product storage
- Gen IV separations development
- Spent fuel treatment facility scoping design
- Advanced process development
- EBR-II spent fuel treatment

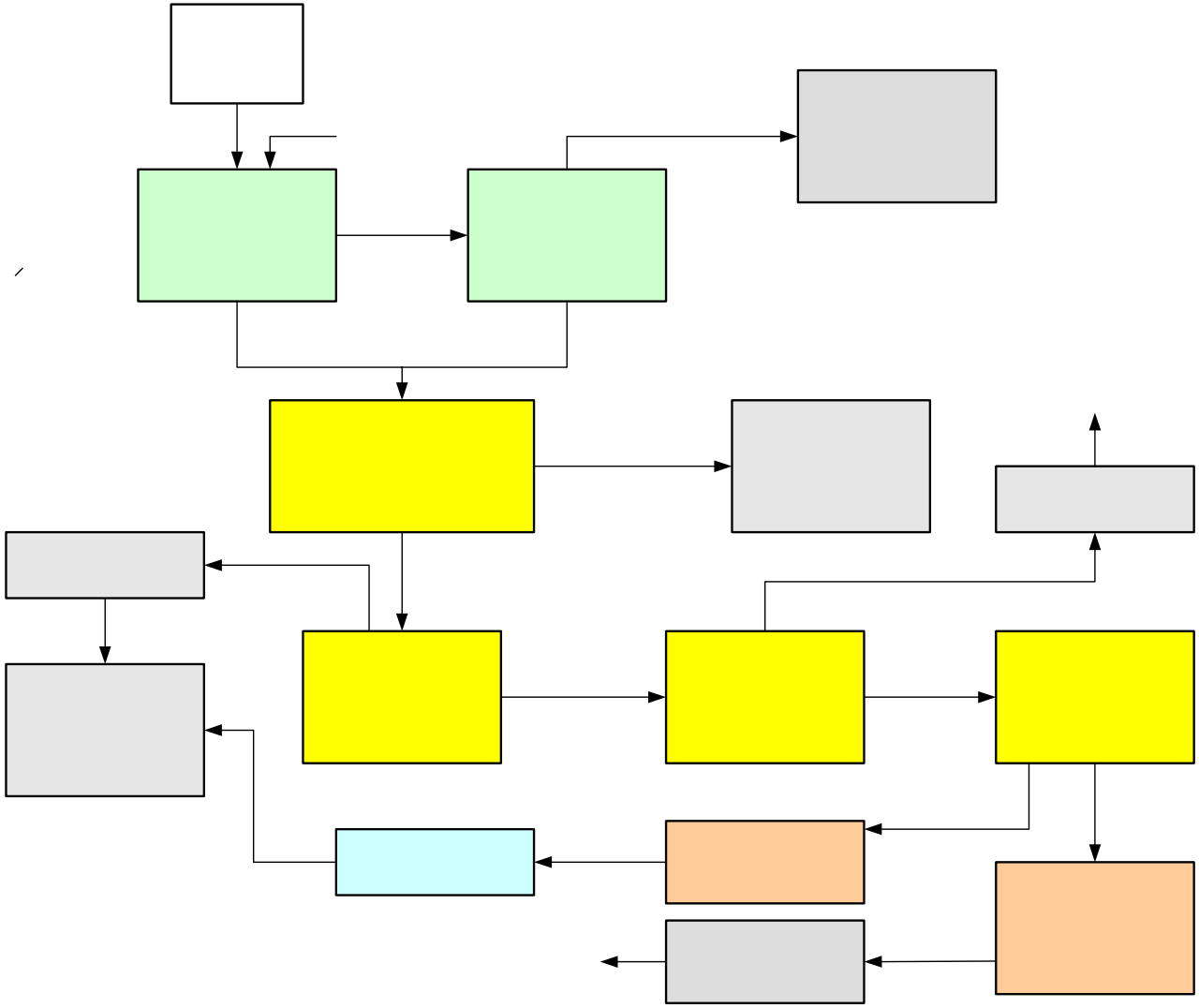
Funding History and Projections ($K)

Activity	*FY-02*	*FY-03*	*FY-04*	*FY-05*	*FY-06*	*FY-07*
Program integration	0	0	400	400	400	400
Advanced aqueous separations	2115	3160	4950	8500	9000	9500
Pyrochemical separations	1470	2400	600	1000	1500	1500
Engineered product storage	100	805	350	600	1000	1000
SFTF scoping design	0	1660	350	500	500	500
Gen IV separations	2810	250	1350	1500	2000	2500
Adv. process development	0	1080	3050	4000	6000	6000
EBR-II spent fuel treatment	29500	21087	18000	18000	18000	18000
TOTAL	35095	30442	29100	34500	38400	39400

AFCI Separations – Technology Applications

- **LWR/ALWR/SCWR spent fuel**
  - Aqueous process (UREX+)
  - Hybrid aqueous/pyrochemical process
- **VHTR spent fuel**
  - Mechanical/aqueous process
  - Pyrochemical process
- **GFR spent fuel**
  - Hybrid pyrochemical/aqueous process
- **LFR/SFR spent fuel**
  - Pyrochemical process
- **MSR fuel**
  - Pyrochemical process

Basic UREX+ Process



LWR Spent Fuel

Long-Range Strategy

Phase 0

Phase 1
Separations for Waste Management

Phase 2
Thermal Recycle of Pu/Np

Phase 3
TRUs to Dedicated Burners

Phase 4
Entry into Gen IV Economy

NOTE: in all phases,

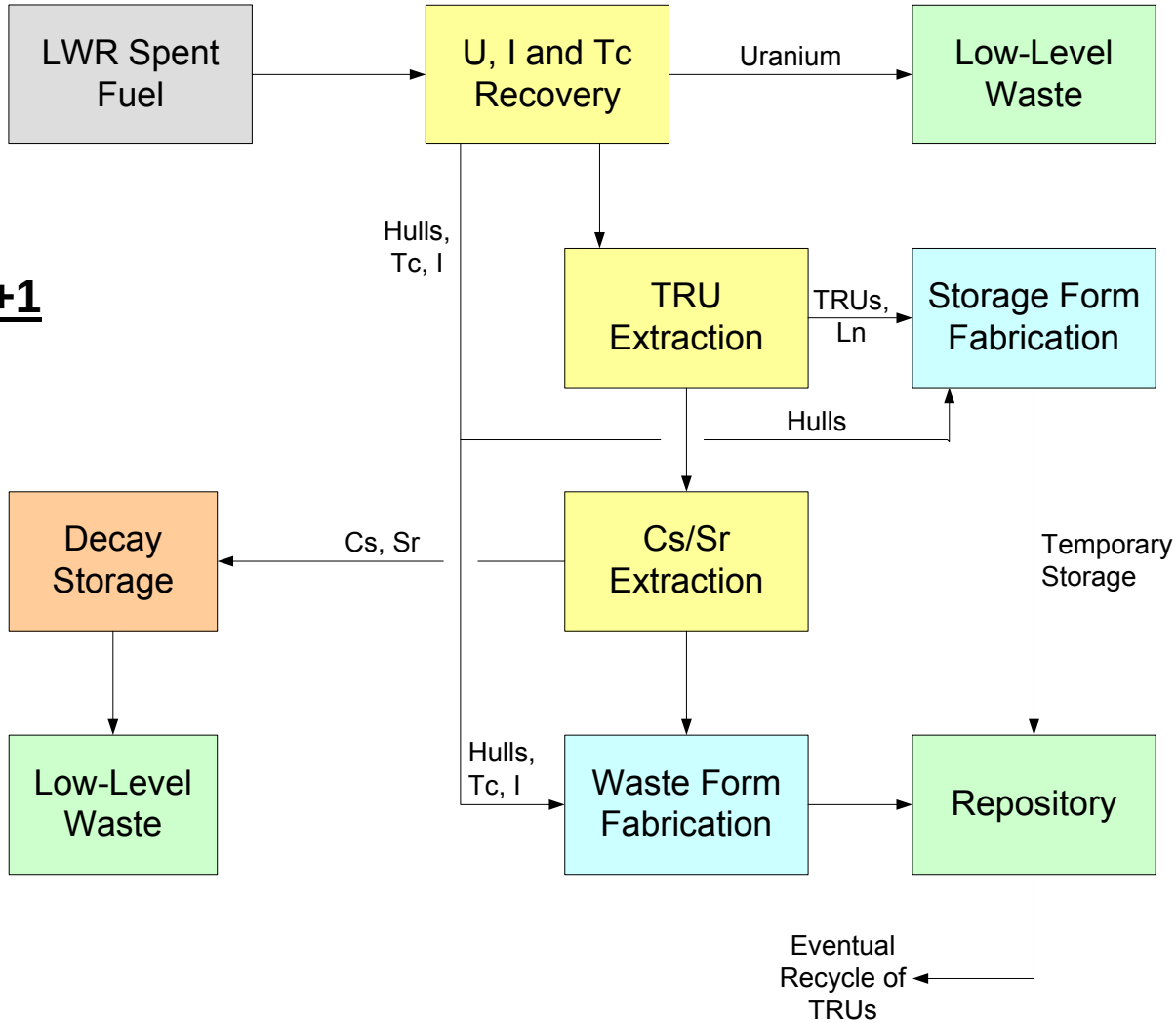
- Uranium is extracted in pure form for disposal as low-level waste
- Cesium and strontium are extracted for separate decay storage and ultimate disposal as low-level waste
- Technetium and iodine are recovered and placed in durable waste forms for disposal as high-level waste

Phase 1: Separations for Waste Management

- **LWR spent oxide fuel can be treated by UREX+ process**
  - Uranium separated for disposal as low-level waste
  - Technetium and iodine separated for immobilization in HLW form
  - Cesium and strontium separated for decay storage
  - Transuranics separated as oxides for temporary storage
- **Issues are related to TRU storage form**
  - Store as oxides, with fission products, for subsequent retrieval and further processing for recycle
  - Store in the form of inert matrix fuel/target rods, using cladding hulls as matrix
    - Potential for permanent disposal
    - May drive future core design

Phase 1 Processing

UREX+1



Benefits of Phase 1 Processing

- **Waste volume greatly reduced by elimination of uranium content; waste package costs reduced**
  - Fewer or smaller waste packages, less expensive materials
- **Iodine and technetium placed in durable waste forms**
- **Short-term heat load reduced: cesium and strontium extracted for separate decay storage, eventual disposal as LLW**
- **Transuranics separated with lanthanide fission products**
  - Temporary storage in repository; inexpensive packaging
  - Self-protecting for up to 50 years
  - Retrieved and processed for use as fuel once there is a national capability to accommodate this material
- **Overall, significant reduction in waste volume and heat load**

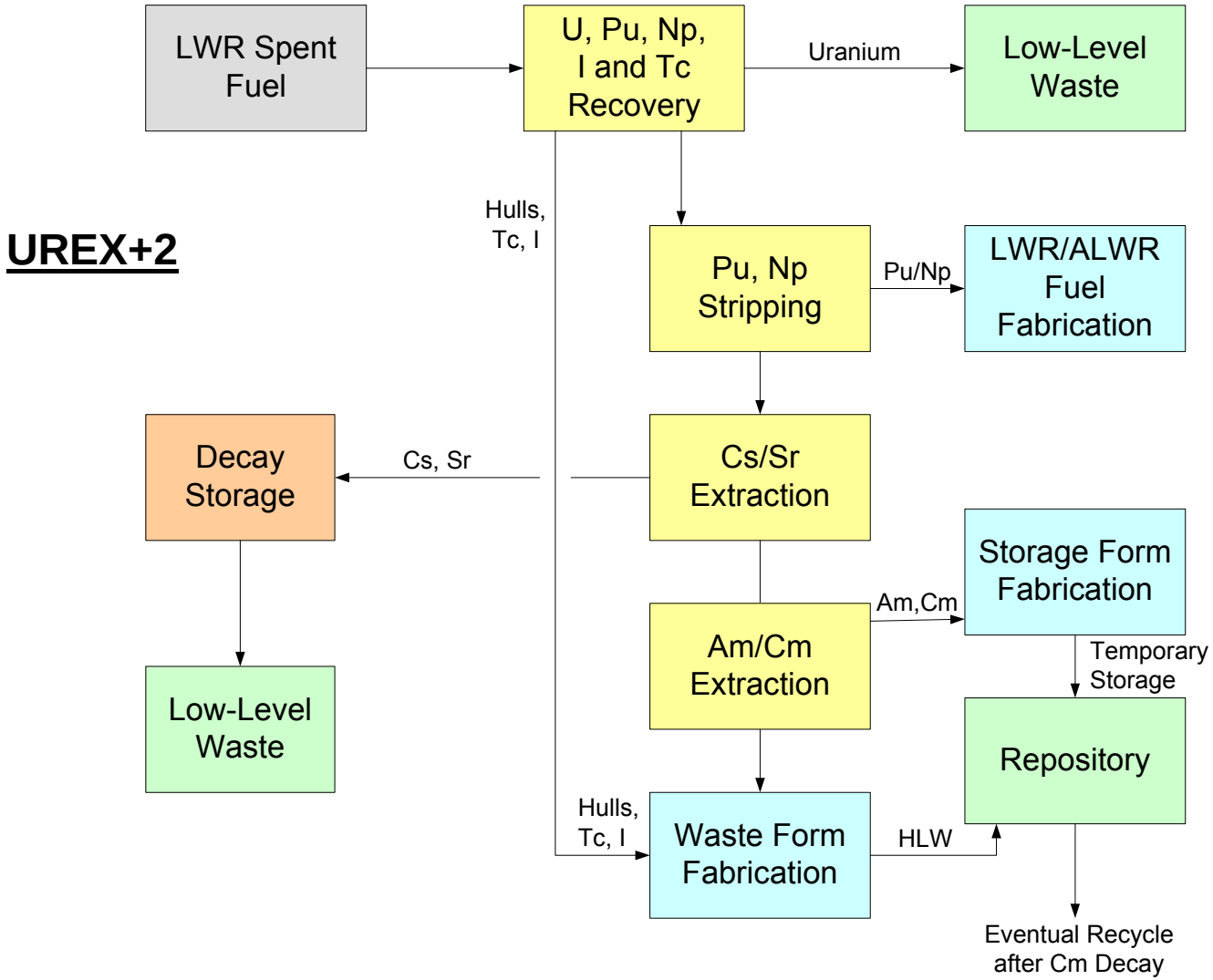
Phase 2: Thermal Recycle of Pu or Pu/Np or Pu/Np/Am

- **LWR spent oxide fuel can be treated by UREX+ process**
  - Uranium separated for disposal as low-level waste
  - Technetium and iodine separated for immobilization in HLW form
  - Cesium and strontium separated for decay storage
  - Transuranics separated as oxides for recycle
  - Requires development of process for Am/Cm separation and development of storage form for Cm
- **Monorecycle as mixed oxide**
  - MOX fuel can be processed for waste management purposes, using the UREX+ process
- **Multi-recycle as mixed oxide**
  - UREX+ process can be utilized without problems

Phase 2: Thermal Recycle of Pu or Pu/Np or Pu/Np/Am (continued)

- **Recycle as inert matrix fuel**
  - Aqueous processing of inert matrix fuel could present a problem if the matrix is yttria-stabilized zirconia
    - Requires addition of fluoride ion (as HF), with attendant corrosion problems
    - Fluoride ion can reduce separation efficiencies
  - Not a problem if the matrix is magnesia (MgO is soluble in nitric acid)
    - Reason for CEA preference for MgO matrix
  - Hybrid process may be appropriate in the case of zirconia matrix
    - Use pyroprocess to convert to acid-soluble form such as chloride or to remove bulk of Zr by chloride volatilization
  - Pure pyroprocess could also be appropriate
    - May be practical due to higher burnup, smaller quantity of fuel to be processed

Phase 2 Processing



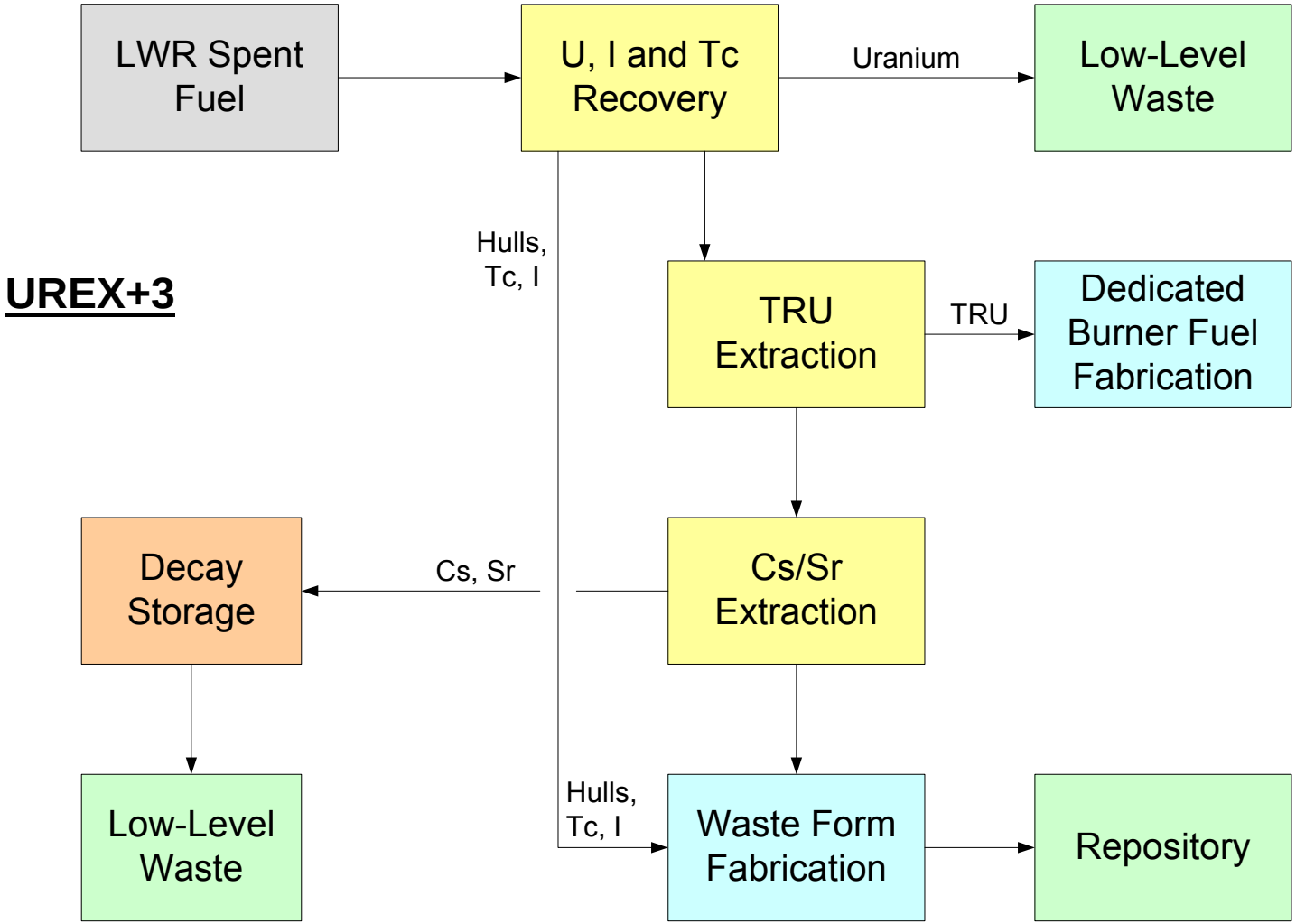
Features of Phase 2 Processing

- **Introduced when mixed oxide fuel containing Pu, Pu/Np, or Pu/Np/Am is qualified for commercial LWR use**
- **Introduction may be evolutionary, as reactor owner-operator acceptance is gained over time**
- **Potential fuel cycle cost savings may approach 1 mill per kW-h_e due to reduced disposal costs, reduced on-site storage requirements**
- **Repository benefits:**
  - Reduced volume of waste to be disposed
  - Greatly reduced heat load associated with waste
  - Compact, durable waste forms
- **Am/Cm product (or only Cm, if Am is recycled) is intended for temporary retrievable storage only**

Phase 3: TRU Burning in Dedicated Fast Reactors

- **LWR spent oxide fuel can be treated by UREX+ process**
  - Uranium separated for disposal as low-level waste
  - Technetium and iodine separated for immobilization in HLW form
  - Cesium and strontium separated for decay storage
  - Transuranics separated as oxides for recycle, subsequently converted to metal or nitride form
  - No separation of Am from Cm assumed
- **Recycle of fast reactor fuel would be by means of pyroprocessing**
  - Technologies already proven in principle at laboratory scale

Phase 3 Processing



Features of Phase 3 Processing

- **Dependent on rate of introduction of fast-spectrum burner reactors**
  - Could proceed in parallel with Phase 2 for some period of time
- **Same repository benefits as Phase 2**
- **No further requirements for temporary retrievable repository storage of separated products**

AFCI Separations - Key Issues

- **Advanced Aqueous Separations**
  - Optimization of UREX+ flowsheet for simplicity, efficiency
  - Improvement of Cs/Sr extraction process; efficient stripping
  - Development of stable extractants for recovery of Am and Cm
  - Development of process for separation of Am from Cm

- **Pyrochemical Separations**
  - Development of hybrid process (chlorination of TRU oxide product followed by dissolution and aqueous separation)
  - Development of pyrochemical process for Cs/Sr extraction

AFCI Separations - Key Issues (continued)

- **Engineered Product Storage**
  - Development of storage forms for Am/Cm and Cs/Sr
  - Thermal and radiological analysis of product storage vehicles
  - Evaluation of storage issues for Cm product
  - Development of innovative packaging concept for temporary repository storage of TRU product and Am/Cm product

- **Spent Fuel Treatment Facility Design**
  - Development of process model that can be used to simulate large plant operations reliably

AFCI Separations - Key Issues (continued)

- **Generation IV Separations Development**
  - Development of processing methods for treatment of TRISO fuel and GFR carbide fuel
  - Development of processing methods for treatment of inert matrix oxide fuel
- **Advanced Process Development**
  - Development and evaluation of advanced head-end process concepts
    - Actinide crystallization process
    - Voloxidation process
  - Development of advanced equipment concepts
    - Improved dissolver design
    - Real-time on-line chemical analysis methods