REPORT of the ANTT SUBCOMMITTEE

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I INTRODUCTION AND SUMMARY

The Committee met on October 16-17, 2001 with a reorganized Advanced Accelerator Applications (AAA) team. The reorganized group has brought more focus to the program and has made considerable progress in the last several months. They have taken the four broad goals developed by our subcommittee (enhanced long term public safety, provide benefits to the repository program, reduce the proliferation risk from plutonium, and improved prospects for a nuclear power) and turned them into guides for the program by adding appropriate criteria, metrics and options. It is a good beginning and will need continual tune-up as the program advances. We have some advice given later in the report.

The AAA group has identified nine options using various combinations of thermal spectrum, fast spectrum, and accelerator driven systems. All options require a fast spectrum reactor or an accelerator driven system as the final stage. The potential role of the existing commercial power reactors is an important consideration. Understanding it will require a look at the effects of partial core loads of new fuels, potential licensing issues and effects on the economics of the power reactors. In our last report to NERAC we estimated that 12 to 18 months of analysis would be required to reduce the large number of options down to a few for further R&D and evaluation. The AAA team agrees with this time schedule and we expect the results of the selection process to be available around the summer of 2002.

Plutonium Separation Policy will be a complicating issue. Spent fuel partitioning is required for any form of transmutation but several alternatives exist. In Europe and Japan plutonium is separated in a pure form from spent fuel and burnt as MOX in Light Water Reactors (LWR's). After this burn the isotopic mix of plutonium is such as to create great difficulties in using it for weapons. This mode allows for separate treatment of the plutonium and minor actinides in the early phases of transmutation and brings them together only in the final phases.

Other possibilities include keeping the plutonium and minor actinides together throughout the treatment cycle which creates real problems in fuel development after the first few cycles of treatment; and a middle ground which removes part of the minor actinides after each stage of treatment and simplifies the fuel development problem.

A combination of technology and policy guidance is required to make a choice. For the present, we have urged the AAA team to keep their options open and not to make any assumptions on their own of what the United States Government will or will not allow.

Work on Roadmap II has begun. It is not possible at the present stage of the program to give all of the detailed milestones, schedules and budgets that were given in Roadmap I.

Rather, Roadmap II should be viewed as a living document which is continually updated as the program progresses. Realistic goals and milestones for the next five years should be included but the Roadmap will necessarily become more vague beyond that. It should be continually updated as the program proceeds. The DOE team has made a very good beginning.

Prospects for international collaboration appear to be improving. There is great interest in transmutation in Europe and Japan and the programs in these places are ahead of ours in some areas. Europe, in particular, has carried systems studies further, particularly for options including plutonium burning as MOX fuel in light water reactors. The OECD's Nuclear Energy Agency is about to officially release an excellent report on options and issues. France has carried out detailed studies on systems that can best use their existing infrastructure.

Everyone is struggling with a shortage of the test facilities required to advance the program. At present spallation targets can only be tested at a power level of 1 MW using proton beams available at the PSI Laboratory in Switzerland and at LANCE at Los Alamos. Fast spectrum and transient testing is needed for fuel development. The only fast spectrum reactors now operating are in France and Russia and the one in France is scheduled for shutdown in 2006. Only laboratory-scale facilities for separation exists.

The subcommittee asked for and received briefing on the test facility topic at our October meeting. We asked the AAA team to assume that the Accelerator Demonstration Test Facility (ADTF) would be ready in ten years with its target and materials testing station and to further assume that the sub-critical multiplier (SCM) would start up about three years later. Based on those assumptions the test facility situation is as follows:

> Target testing facilities exist at the 1MW level and these will be adequate for the next five to seven years. Higher power will be required after that. 2MW beams should be available from the Oak Ridge Spallation Neutron Source, but if still higher power testing is needed before the start-up of the ADTF the only possibility in sight is an upgrade to the LEDA facility at Los Alamos.
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> The Fuels testing situation is similar. The INEEL Advanced Test Reactor is available for thermal testing. For fast spectrum testing, the PHENIX facility in France and the BOR 60 facility in Russia exist.. However, the French facility will only be available for the next five years and the long term prospect for the Russian reactor are unknown. If our Fast Flux Test Facility (FFTF) were restarted as part of some other program it would greatly help. Transient Testing requires a new facility or restarting the ANL-W Transient REActor Test (TREAT) facility.
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> Separation facilities are available for the next four to five years for small scale system development. After that a new facility will be needed for intermediate scale operations.

Target-subcritical-multiplier coupling testing can be done for the next three or so years at foreign facilities. An upgrade to a U.S. facility (ZPPR) might carry the load for four or five years beyond that, but is problematic.

All regions interested in transmutation face the same test facility problem. None can proceed alone without construction of all the needed test facilities which would be very expensive. Self-interest is the driver behind the move toward international collaboration. This is a good thing because this is a much more effective motivation than pure altruism.

Finally, we wish to congratulate the revitalized AAA team for the excellent work that they have done.

II. GOALS AND CRITERIA

The Subcommittee is pleased that the Program has proposed goals during the October 2001 meeting that correspond reasonably to those set forth in the Subcommittee's report of its April 2001 meeting. We understand that the Program wants to avoid the suggestion that it is in competition with the Yucca Mountain repository. However, as the Program's proposed goals are now less specific, they put a greater burden on interpretation and the choice of suitable objectives and criteria. With this understanding, the Subcommittee recommends that the Program adopt the goals it has proposed with a change in goal 3 to broaden it to include all potential sources of Plutonium:

1. Enhance long-term public safety
2. Provide benefits to the repository program
3. Reduce the proliferation risk from plutonium
4. Improve prospects for nuclear power

The Subcommittee understands that "public safety" in Goal 1 refers to a reduction in radiological health impacts from spent nuclear fuel, as compared with a once-through approach. Such a reduction has to be a net reduction, balancing—using some kind of discounting to account for the uncertainties of the future—long-term reductions against what would likely be some near-term increases in view of increased fuel handling and processing. Such near-term costs have to include the vulnerabilities of fuel cycle facilities to accidents and, after September 11, to deliberate attacks to spread radioactivity. Consideration of the latter—the possibility of deliberate harm—would probably fit more naturally together with proliferation under the third Goal.

The Subcommittee understands the benefits in Goal 2 to mean near-term benefits in the design of the repository program, that is simplifying and reducing the cost of follow-on repositories after the first one, or delaying the need for them.

When it comes to reducing proliferation, as in the case of reducing radiological health effects, there needs to be a balancing of long-term advantages against near-term costs. That is, the Program justification has to balance the reduction in access to nuclear explosives in the long term—as compared with a once-through approach—against the likely increase in access to such materials in the short run by virtue of increased handling and processing of such materials. After September 11, the meaning of "proliferation" must include theft of nuclear explosives by non-state actors.

Finally, the last category is a catchall. It definitely includes the economics of nuclear power and the possible increased acceptability to those concerned about the long-term impact of nuclear waste. Again, there is a balancing—the increased near-term fuel cycle cost against the putative feeling that one is dealing more responsibly with the future.

The Subcommittee has a number of recommendations in the Objectives/Criteria category. It will keep these fairly general to allow the Program flexibility and so as not to detract from some essential points. Choosing appropriate criteria is much more important than choosing specific restrictive metrics. The Subcommittee believes the metrics can be more flexible at this point and that some of the numerical ones the Program proposed in the October 2001 meeting were overly restrictive. Let us consider the Goals one by one:

1. <u>Enhance long-term public safety</u>

   The Subcommittee believes that as the goal refers to reduction in radiological health effects, so should the criteria. Proposed Criterion 1.2 (Reduce radiation dose to future inhabitants of repository region) meets this test. Proposed Criterion 1.1 does not and we will return to it. The Subcommittee does not recommend a specific metric under 1.2, but believes that any metric should make clear the time-scale over which it applies. Here, what happens in the next few thousand years, or ten thousand years, is more important than what happens several hundred thousand years from now, not to speak of a million years from now.

   To take account of the cost of attaining the long-term benefits, there needs to be another criterion such as, "the transmutation process will not significantly increase near-term radiological doses". The radiotoxicity calculation that underlies Proposed Criterion 1.1 is interesting and suggestive, but as it does not translate into radiological dose it is inappropriate in this context. DOE does not use it in evaluating the proposed Yucca Mountain repository. The radiotoxicity standard is a drinking water standard. It basically compares situations in which the surrounding population drinks diluted nuclear waste at the source and asks how much dilution is needed to make the drinking water safe. It does not take account of the different transport times from the source—which is not realistic in evaluating the possible harm to the surrounding population. In short, the radiotoxicity curves can only be considered as a rough guide, but are a misleading guide to policy decisions in the waste area.

2. Provide benefits to the repository program

The heat load criterion 2.1 should refer to the heat load that drives the repository design, not merely the heat load after 500 years. Sub-criteria or metrics under this criterion could refer to heat load and mass, and so on, insofar as they affect design and cost. (The program must ultimately come to grips with cost issues.) These criteria should also involve a balancing of repository waste reductions against increases in low-level and medium-level waste formed as a consequence of increased processing of waste.

Criterion 2.2- " Delay need for more repositories" might be a better formulation.

3. Reduce the proliferation risk from plutonium

The Subcommittee recommends expanding the category of waste to include military waste. The three Criteria are more or less in the right direction but need to be augmented, especially in the light of September 11.

First, Criterion 3.3 has got to say more than "minimize potential for diversion". No one is going to put up with increased risk of accessibility to nuclear explosives by hostile states or terrorists in the near term for benefits hundreds of years from now or later. Criterion 3.3 has to say "no significant increase in accessibility to nuclear explosives over the once-through fuel cycle". Moreover, and especially after September 11, it would be irresponsible to ignore the possible increased vulnerability to radiological sabotage of the increased number of facilities and material movements that transmutation entails. Proliferation has to be understood to cover terrorist attacks on fuel facilities and transportation. Hence, a new Criterion 3.4 might be added; "no increase in sabotage vulnerability". This vulnerability can be defined away, at least to an extent, by positing enough protection, but then the increased cost has to be factored in.

4. Improve prospects for nuclear power

We are talking about making nuclear power genuinely more attractive. The basic issue here is the balance between long term environmental and health benefits and short-term costs. The underlying notion is that the long-term waste problem could be demonstrated to be one of shorter duration—hundreds or thousands of years as opposed to tens or hundreds of thousands of years. If this is true, it still has to be balanced against the likely higher cost of a transmutation option—no one suggests it could be cheaper. This point is covered, somewhat indirectly, in Criterion 4.1, the Viability Criterion, except that the metric has to be in terms of cost. Moreover, in making cost comparisons of costs and benefits separated in time, the Program analysis should apply a suitable discount factor. Otherwise such comparisons are not serious. This is a hard test, but it is a challenge the Program will have to face if it is to have a future. It is made more difficult because some of the benefits, reduced Plutonium inventory and reduced potential long term radiation, are hard to quantify economically.

Criteria 4.2 and 4.3 are acceptable but need to be carried through consistently in the metrics.

III. SELECTION AMONG ALTERNATIVES IN THE SYSTEM STUDY

The AAA program is analyzing alternative system architectures and preliminary results were provided to the ANTT subcommittee. The study comprises an in-depth assessment of the nuclear power system in the United States under the assumption that partitioning and transmutation of spent nuclear fuel will be an integral part of the system. A total of nine cases were examined that reflect the different approaches and technologies that could be employed. The cases span the approach/technology space and provide essential insight into the role that fundamental technology parameters play with respect to the efficiency and effectiveness of the entire nuclear system.

Using the knowledge gained to date, the AAA plans to reduce the number of cases from nine to a more workable number that define the research and development needed by the AAA program. This down-selection is a program milestone and the down-selection process should occur over the next nine to twelve months. At the same time, goals, criteria, and metrics are being refined as indicated in the previous section of this report. The combination of insight gained from the calculations at hand and the revised set of goals, criteria and metrics should provide a sound basis for down-selection, if the impact of externalities is taken into account. A number of externalities exist which are not contained in the goals, criteria, and metrics. One example of an externality is the extent to which it will be possible to separate plutonium in the United States. If plutonium may not be separated, and transuranic streams are to be employed, another externality is the extent to which the commercial nuclear industry in the United States would embrace fuel containing certain higher transuranic isotopes. A third is the extent to which the commercial nuclear industry would embrace non-fertile fuel. With such externalities in mind, prudence in down-selection is recommended. Such prudence would dictate that the remaining cases continue to span the approach/technology space.

In spite of externalities, the system study does reveal certain fundamental aspects of a nuclear system with partitioning and transmutation. Among these are:

(1) The role of the commercial power reactors in Tier 1 is significant and should be included,
(2) A fast spectrum transmuter is needed to complete the destruction process, regardless of the effectiveness of Tier 1 and might be either an accelerator driven system or a fast spectrum reactor,
(3) Separation effectiveness does not need to be as thorough as now assumed, i.e. 0.1%, and it is possible that this requirement may be relaxed,
(4) Non-fertile fuel significantly improves the destruction rate, and at least partial loads of such fuel may be essential to the effectiveness of both Tiers 1 and 2.

Given these fundamental aspects of a nuclear system with transmutation and partitioning, it should be possible to initiate research and development without significant risk, and to fine tune these development programs as new information is obtained from the systems study.

IV. FUELS

There are nine approaches currently being considered by the AAA program. Each of these approaches assumes currently-operating LWRs serve as Tier 0 reactors. In multi-tier approaches, Tier 1 reactors burn plutonium or plutonium plus other transuranics (TRU) in thermal reactors (currently operating LWRs, a newly constructed advanced LWR, or newly constructed gas-cooled reactors). Fuel for this tier is in solid pellet form, similar to that used in operating reactors, or TRISO particle form, similar to that used in gas-cooled reactors. The compositions include either separated PuO_2 or PuO_2 with Minor Actinides (MA) in fertile (mixed with depleted UO_2) or nonfertile mixes (in an inert matrix material such as ZrO_2). Candidate Tier 2 reactors include subcritical accelerator driven systems (ADSs) with nonfertile fuel and fast reactors with uranium-based metal fuel. Candidate Non-Fertile Fuel (NFF) forms being considered for the Tier 2 ADS include a TRU-Zr metal alloy, a mixed nitride pellet, a mixed oxide pellet, and a nitride particle fuel dispersion in a metal Zr matrix. In the single tier fast system approach, the AAA program considers a subcritical ADS using nonfertile metal fuel and a critical fast reactor using uranium-based metal fuel.

Presentations by the AAA program indicate that laboratory-scale demonstrations for fabricating candidate NFF forms are underway or are being developed. Laboratory measurements of thermo-physical properties (specific heat capacity, thermal conductivity, phase diagrams, coolant and cladding compatibility, etc.) to support irradiation testing and fuel performance model development are being conducted, and data are to be collated into an AAA Fuel Properties Handbook. Eventually, models will be developed to predict fuel behavior and benchmarked against available data.

An experiment description document has been prepared for the first fuel irradiation tests that will be conducted at the INEEL Advanced Test Reactor (ATR) and submitted to the ATR for review. These initial tests will include representative fuels for nonfertile oxides (Tier 1 and 2), metal alloys (Tier 2), mixed nitride pellets (Tier 2), and mixed oxide pellets (Tier 2). Initial ATR tests are designed to simulate operating conditions. Data will be obtained to provide an indication of fuel irradiation performance (fission gas generation and release, helium generation and release, fuel swelling, fuel/cladding chemical interactions, phase formation and stability, etc.).

The AAA team believes that a thorough fuel technology development program is required prior to conducting an integrated systems test in the proposed accelerator demonstration test facility (ADTF). Presentations by the AAA team indicate that in order to accomplish this thermal testing should be completed within five years, and fast spectrum and transient testing should be started within five years. Plans have been developed for conducting thermal irradiation tests in the INEEL ATR. However, it is not clear that facilities for fast and transient testing will be available in the desired timeframe. If fast spectrum tests can't be conducted in foreign reactors, the only other option identified by the AAA team is restarting the PNNL FFTF. Likewise, transient testing requires restarting the ANL-W TREAT facility or constructing a new facility.

The subcommittee recognizes that the selection of fuels for Tier 1 and Tier 2 systems must consider in-service performance and reliability, safety, compatibility with separations and recycle technologies, and economics. Nevertheless, the subcommittee believes that additional fuels and separation research is needed to support the selection and ultimately, the licensing of fuels currently considered by the AAA program. For example, insights about the viability of candidate fuels can be gained by demonstrating the fabrication process and obtaining fundamental physical properties. The subcommittee is pleased that the AAA program plans to place more focus on fuels and separation issues in the next year.

As part of this increased emphasis on the fuels research and development effort, this subcommittee recommends that research about the fabrication and physical properties of candidate fuels be continued. In addition, the committee recommends that the following items be addressed if still relevant after the reduction in the number of options that is soon to occur:

- Updated program plan. The ADTF Functions & Requirements document and the Transmutation Fuels R&D program developed as part of the 1999 ATW Roadmap have not been updated to reflect programmatic changes and technology advances that have occurred over the last several years. The subcommittee recommends that the Fuels R&D program plan be updated to ensure that the on-going fuels research is addressing the appropriate issues.

- TRISO particle fuel development. Research on Tier 1 TRISO particle fuels has been delayed. It is not clear if this is due to insufficient resources or the program's intent to rely on available test data from TRISO coated particles made years ago by the U.S. or Germany. The subcommittee believes that the US capability to manufacture coated-particle fuel must be re-established and proven to result in similar-quality fuel before assuming that existing data are applicable. This subcommittee suggests that the AAA program consider "teaming" with other U.S.-sponsored HTGR fuel development efforts to reduce unnecessary duplication of effort.

- Materials for assessing the impact of americium. The performance of candidate Tier 1 and Tier 2 fuels containing MA may be impacted by the presence of americium. The AAA program is having difficulty in procuring the americium needed to assess this impact because DOE-EM is moving such materials into DOE's waste management program. The subcommittee recommends that appropriate actions be taken by DOE to assure procurement of necessary americium.

- Tier 1 Fuel. Additional research is needed to understand the performance of an entire core consisting of NFF or mixed oxide fuel. Although it is not part of the fuels development program, the willingness of the commercial power industry to use Tier 1 NFF in a commercial reactor must also be considered. The subcommittee believes that DOE must fund licensing of this fuel or utilities would be reluctant to embrace this technology.

V. PARTITIONING (SEPARATIONS) TECHNOLOGY

A Separations Working Group has been formed and progress and plans for FY2002 were reviewed at our October 15, 16 2001 meeting. In the first step of the selected partitioning scheme, spent LWR fuel will be subjected to a chop-leach dissolution process and iodine will be removed when the fuel is dissolved in nitric acid. UREX, a solvent extraction process using the extractant tributyl phosphate (TBP) similar to the well known PUREX process, can then be used to extract uranium that is sufficiently decontaminated to permit its disposal as low level waste. Batch tests have shown 99.999% recovery of uranium with contamination from technetium, neptunium, and plutonium many orders of magnitude lower than necessary for classification as Class C waste. The key to this process is the use of the new complexant/reductant acetohydroxamic acid (AHA) which inhibits the extraction of Np and Pu and complexes important fission products such as Mo, Zr, and Ru to prevent their contamination of the separated U and Tc product streams. AHA is a big improvement over the ferrous sulfamate used in the PUREX process because upon calcination AHA decomposes to the non-toxic volatile components (hydrogen, carbon, nitrogen, and oxygen). Thus the volume of waste is not increased nor are any metal ions added to the waste. Tc is stripped from the U raffinate and targets can be fabricated for subsequent transmutation. Fission products can be removed from the extracted transuranic (TRU) fraction and prepared as a high level waste form for repository disposal. The TRU fraction can then be incorporated in an appropriate form for future irradiation and transmutation.

A better understanding of AHA chemistry is required prior to scale-up of UREX to pilot plant size and a full UREX "cold" demonstration involving both hood and glovebox phases and a multistage contactor test were conducted. The measured values of U, Pu, Np, and Tc in the various phases were compared with predictions from AMUSE, a universal computer model developed for solvent extraction. It was concluded that the experimental U, Np, and Tc values met the predicted target goals. However, it was found that AMUSE predicted trends, but not exact values, and that the predictions were not as good as would have been expected. The Pu remaining in the Tc and U strips was 0.16% and 0.13%, respectively, which did not meet the target goals and illustrated the need for obtaining better data for the complexation constants for Pu with AHA to feed into the model. More data in addition to those available in the literature on the effects of such variables as temperature, solvent and extractant concentrations, etc. under model-specific conditions are also needed.

Future directions and challenges include gaining a better understanding of AHA-actinide complexation and instability. Demonstrations of countercurrent extractions with simulated and then with actual commercial fuel solutions are needed and should be followed by scaleup to pilot-plant size and integration with overall partitioning and waste treatment schemes.

A hot demonstration of UREX utilizing existing hot cell facilities at the Savannah River Technology Center (SRTC) is planned for April 2002 with 3.9 kg of Dresden reactor spent fuel. A 33-stage centrifugal contactor train will be installed in the SRTC hot cell for this experiment.

Conversion of the uranyl nitrate from UREX to uranium trioxide is being studied at ORNL. After establishment of process parameters, a smaller scale unit will be installed as part of the UREX hot demonstration at SRTC.

Investigations of the PYRO-A process to recover TRUs from the UREX product using direct electrolytic reduction are continuing. The PYRO-B process development for treatment of metallic transmuter fuel (TRU-75 wt. % Zr) has shifted to a direct electrorefining process which is more favorable for a fuel composition of ~50 wt.% TRU.

Plans for FY-2002 include: complete the design of an optimized UREX flowsheet; conduct hot demonstrations of the UREX process at SRTC; evaluate AHA radiation stability; demonstrate modified direct denitration process of the uranyl nitrate from UREX; demonstrate the PYRO-A process at lab scale; demonstrate the PYRO-B direct electrorefining process with metal alloy fuel; demonstrate direct electrorefining of nitride fuel; evaluate concepts for cermet fuel treatment; develop process concepts for TRISO fuel processing.

In a general discussion of facilities required for the longer term, it was pointed out that it might be possible to install UREX at existing facilities in the U. S. such as GE Morris or Barnwell, but that there are no existing facilities for accommodating the PYRO processes. Complicating the problem are high concentration of TRUs making chemical separations with non-fertile fuels and aqueous processing difficult due to reagent degradation and criticality concerns. There is also concern about pyrochemical processing due to increased heat loads in process equipment. Active cooling or dilution of the TRU product will be needed. The presence of the minor actinide (MA) isotopes, e.g., Am-241, 242m, Cm-243,245, Cf-249,251, may necessitate smaller batch sizes, active cooling, and special process equipment. The more recycles the worse the problem becomes, as the MAs continue to build up in thermal cycles.

It may be necessary to partially remove MAs from the Pu in order to help mitigate the severe problems associated with MA buildup. If such procedures are regarded as Pu separation and not allowed because of proliferation or other concerns, then handling and fuel fabrication problems could become very intractable, indeed. Perhaps partial controlled selective removal of the more volatile Am trichloride which has been found to be technically feasible could be used to remove a large fraction of the Am leaving other MAs in the Pu. Calculations would have to be performed to determine whether this would be sufficient to ameliorate the heat and criticality problems. The resulting product should still be proliferation resistant. The final separation schemes to be adopted depend on decisions about Pu “conditioning or cleanup” and on the spectrum of the reactors or transmuters to be used in the subsequent multi-tiered approach.

VI. ROADMAP

DOE, at the direction of Congress, submitted its first Roadmap for Accelerator Transmutation of Waste (ATW) in October 1999. It outlined a long and costly program. Since then much has changed. The Multi-Tier approach which combines initial treatment of spent fuels in thermal-spectrum reactors with subsequent treatment in a fast spectrum system (reactor or accelerator driven) holds much more promise, and DOE has begun work on a new Roadmap based on this approach.

In the Multi-Tier Approach, Tier 0 simply would consist of burning uranium fuel in a Light Water Reactor. Depending upon the specific scheme chosen, Tier 1 would consist of burning either plutonium or plutonium plus other transuranics in a thermal reactor. There could be several, but no more than about three, passes of the transuranic material through Tier 1. Finally, the remaining transuranics from Tier 1 would be cycled an as yet undetermined number of times through a Fast Reactor (FR) or Accelerator Driven System (ADS) before the final radioactive byproducts are sent to a repository for permanent storage. The ANTT Subcommittee looks favourably upon the Multi-Tier Approach. However, as the AAA research team moves forward and DOE revises its Transmutation Roadmap, the Subcommittee makes the following recommendations:

<u>Nomenclature for Alternative Multi-Tier Schemes</u>

The nomenclature used to denote the nine alternative Multi-Tier Schemes in the AAA Choice Tree is difficult to remember and makes the discussion and study of the AAA results laborious and sometimes confusing. A better, more transparent, nomenclature is sorely needed and should be adopted by the AAA and the Roadmap.

<u>Readiness Levels of Various Technologies</u>

The Subcommittee liked the idea of graphically depicting the Readiness Levels of competing technologies, and recommend that this be included in the Roadmap. However, the Subcommittee noted some confusion about the range of the scale, for instance, whether it is 1 to 8 or 1 – 9. Standardization is required.

<u>Compatibility with GEN IV Roadmap</u>

One of the Top-Level Goals as delineated by the ANTT Subcommittee for the AAA R&D is to “Improve the Prospects for Nuclear Power.” AAA should keep in mind that there is another ongoing DOE program to describe candidate technologies for the next generation of nuclear reactors. Those activities are being conducted with heavy input from a NERAC Subcommittee on Generation IV reactors. The results of those studies will be contained in a GEN IV Roadmap. It is extremely important that the AAA and GEN IV teams coordinate their activities so that the “winning” AAA technology or candidate technologies will be compatible with the most promising GEN IV technologies. The Transmutation Roadmap should at least mention the relevant highlights from GEN IV Roadmap and identify those GEN IV outcomes that could impact the AAA down-select process.

Number of Cycles per Tier

The AAA team fully appreciates that the amount of transuranic thermal burning in Tier 1 strongly impacts the amount of fast spectrum burning that is necessary in Tier 2. The ANTT Subcommittee looks forward to an optimization of the Tier 1/Tier 2 burn scenarios. The Subcommittee was unimpressed with estimates of 15 to 20 burn cycles in Tier 2 and recommends that the Roadmap target a lower number of Tier 2 cycles.

Roadmap to be a Living Document

We are at the beginning of serious R&D on future reactor technologies. As more data on the technologies are obtained, the Subcommittee recommends that the Roadmap be continually updated. The Subcommittee does not view this as a weakness in planning but as a recognition of the fact that we are exploring uncharted territory and should remain open to more advantageous technologies.

Highlighting Critical Decision Points in the Roadmap

Certain critical decisions and externalities will drive the Roadmap. An obvious one is whether the country will allow the separation or plutonium so that it can be burned in Tier 1. Obviously, if plutonium separation will continue to be barred, then the whole Roadmap exercise will be driven in the other direction. Such critical decision points should be identified early in our deliberations, and the appropriate governmental officials should be made keenly aware of the need to resolve such critical issues so that the AAA and Roadmap team will not waste their time studying “outlawed” technologies.

More International Collaborations

Although the ANTT Subcommittee has heard a considerable amount about transmutation studies abroad, such as the French study of multiple recycles of plutonium in pressurized water reactors, it would like to know more specifics about joint US participation in such investigations. Moreover, ideas on possible international involvement with the ADTF Future Target Area should be included in the Roadmap.

At this time, the ANTT Subcommittee fully appreciates the long road ahead for the AAA R&D and the development of the Transmutation Roadmap. However, the Subcommittee anxiously awaits the AAA team’s down-selection from nine to about three or less viable alternatives for transmutation systems. Although this down-selection will not occur before the next version of the Roadmap is completed, the final viable alternative technologies should be included in future Roadmap updates.