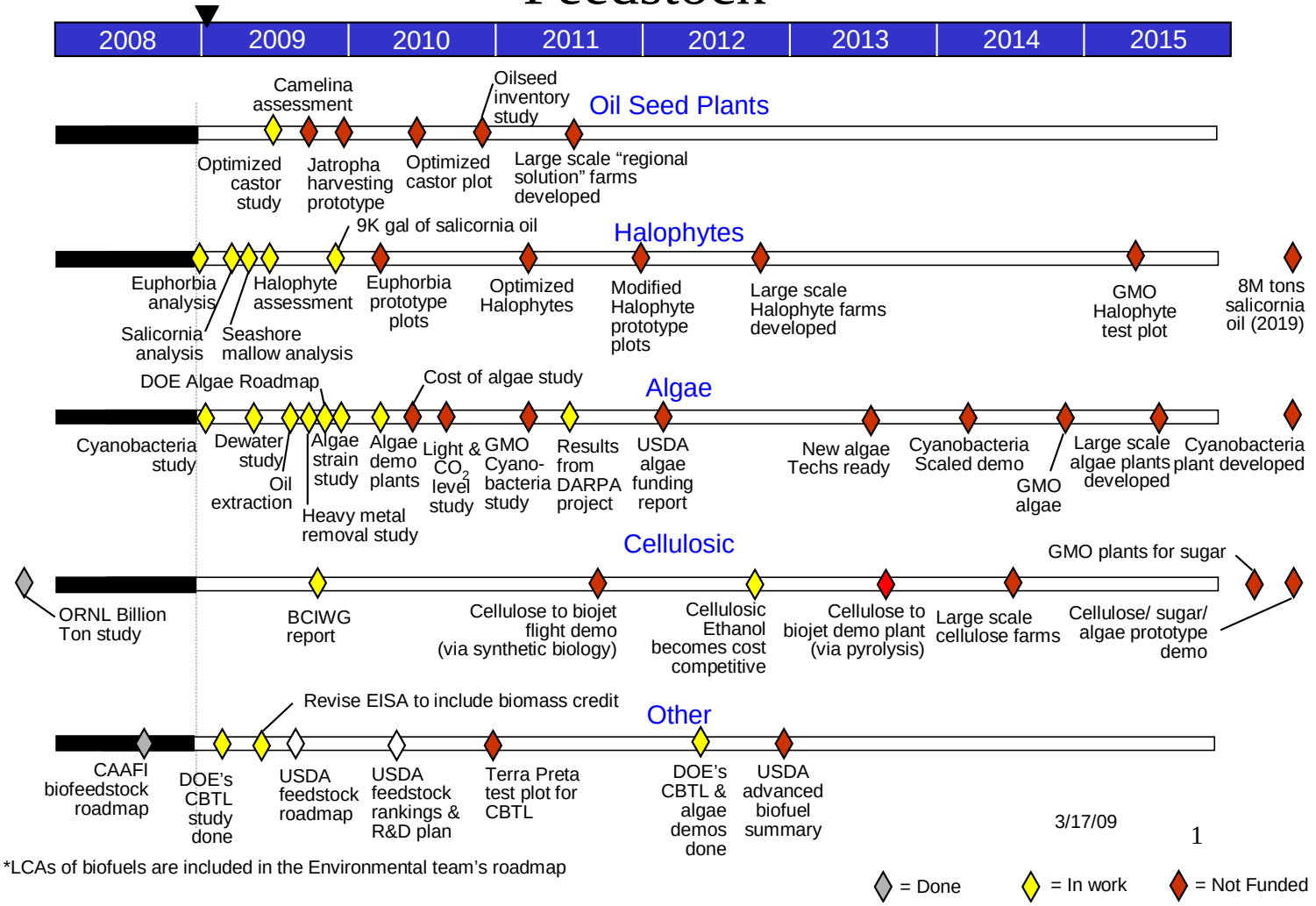
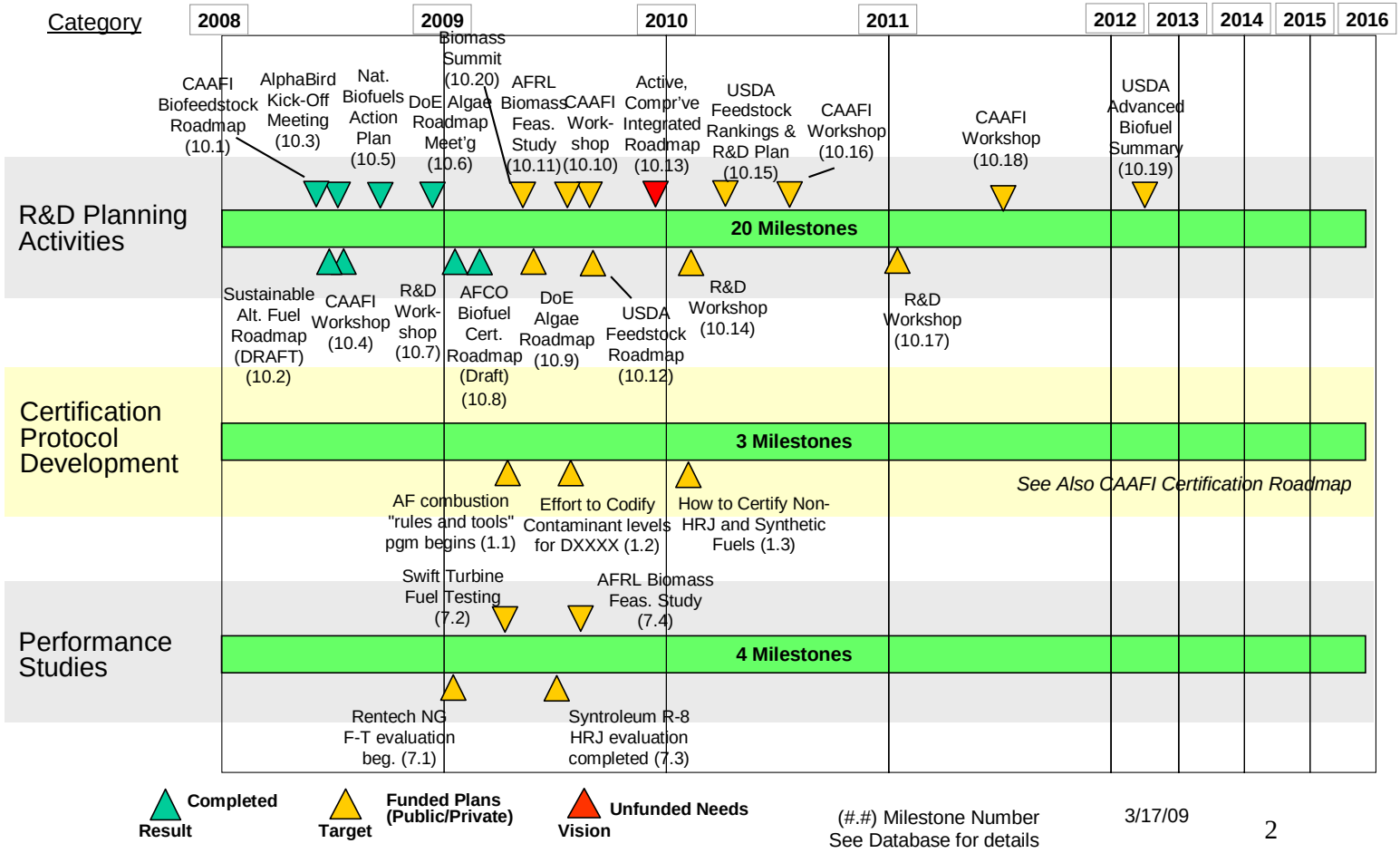
CAAFI R&D Team Roadmap (1 of 6)
Feedstock

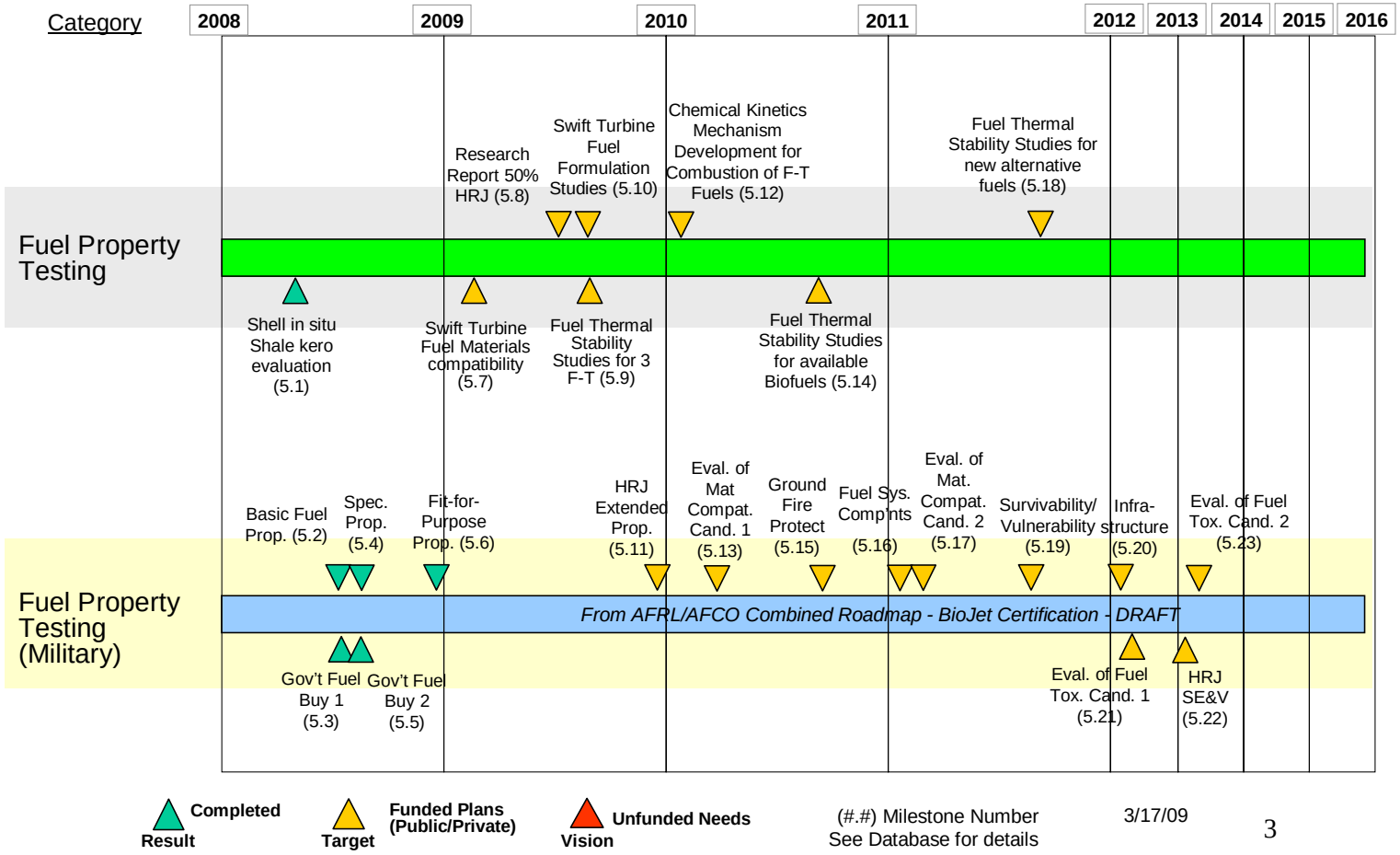


CAAFI R&D Team Roadmap (2 of 6)
Planning, Protocol, and Performance

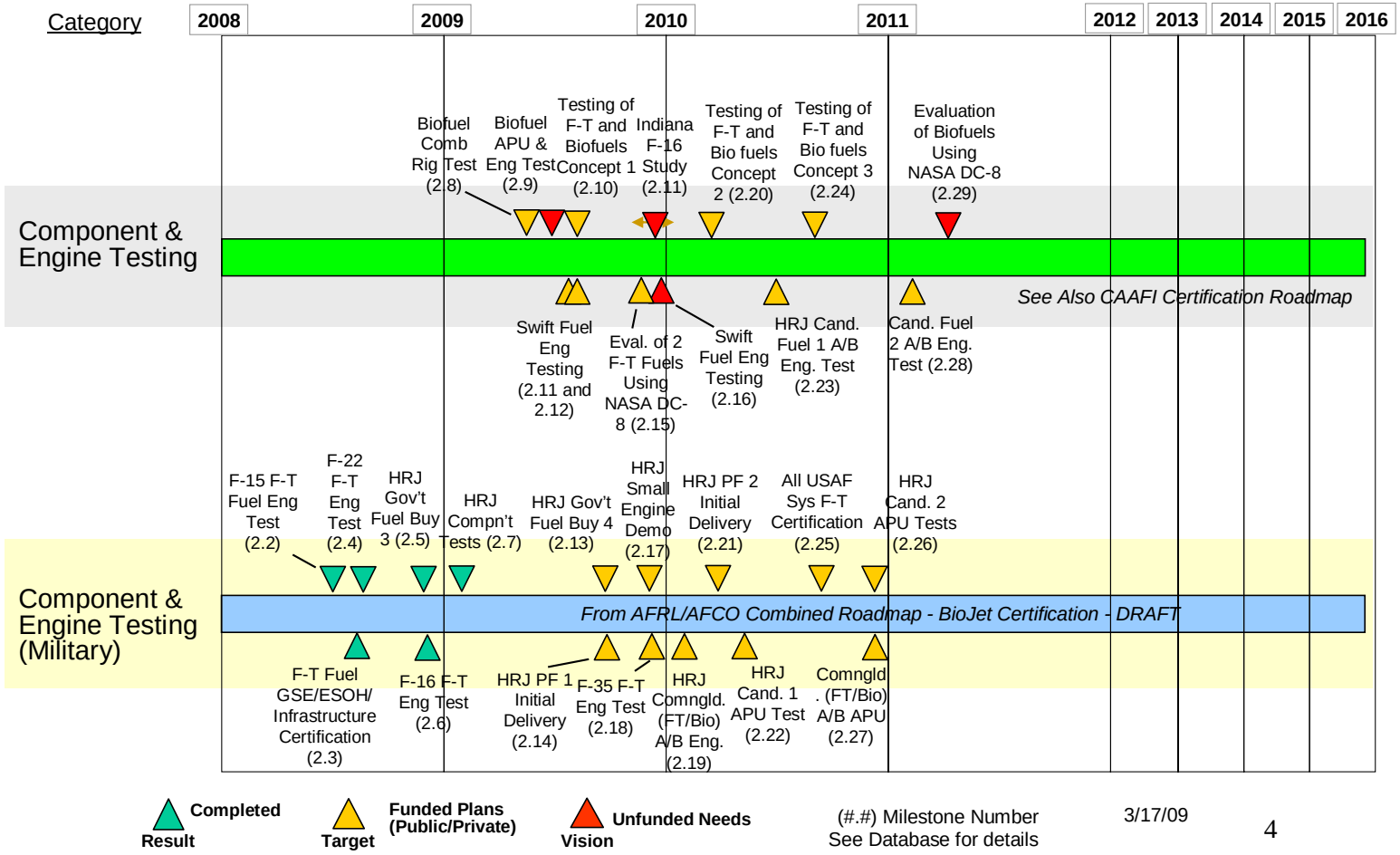


CAAFI R&D Team Roadmap (3 of 6)

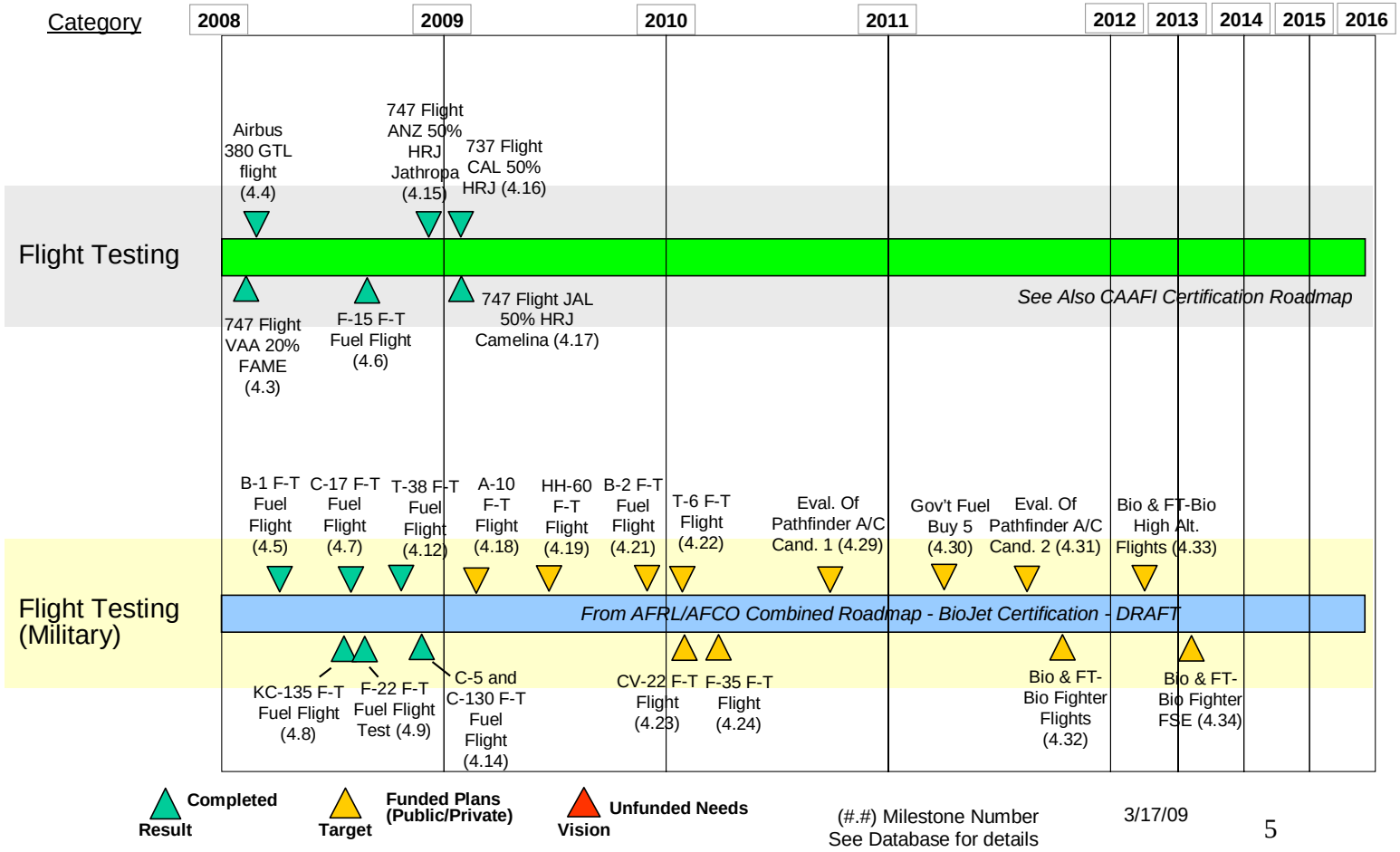
Fuel Property Testing



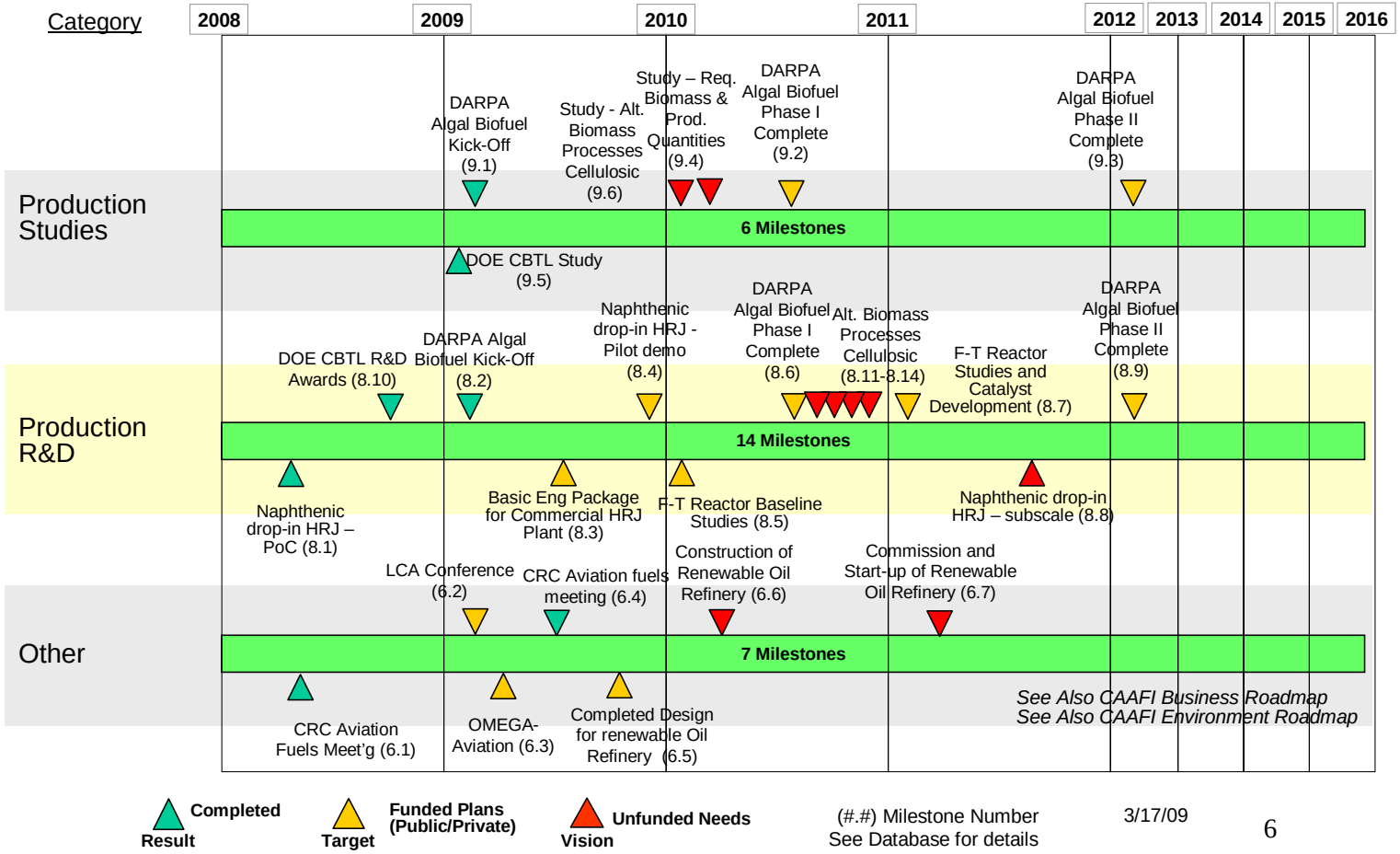
CAAFI R&D Team Roadmap (4 of 6)
Component and Engine Testing



CAAFI R&D Team Roadmap (5 of 6)
Flight Testing



CAAFI R&D Team Roadmap (6 of 6)
Production Studies and R&D



The following text provides descriptions for each of the milestones listed on the Commercial Aviation Alternative Fuel Initiative (CAAFI) R&D Feedstock Roadmap.

Swimlane #1: OIL SEED PLANTS.
(Plants whose seeds contain oil that is suitable for biofuel)

Optimized Castor Study (In Work): A modified Castor plant with about 2X the oil yield of present Castor plants has been developed in the lab and will be tested in large scale plots in Brazil (see below). This could provide biofuel for near-term applications.

Camelina Assessment (Unfunded): This feedstock appears promising for present biofuel applications using fallow farmland in North America. A Life Cycle Assessment needs to be performed.

Jatropha Harvesting Prototype (Unfunded): Jatropha appears promising for near-term oil production without competing for farmland or irrigated fresh water. However, the plant's oil seed currently needs to be harvested by hand, and an automated process needs to be developed to reduce production costs and reduce human contact with the poisonous plant.

Optimized Castor Plot (Funded): The resulting modified optimized castor plant (see above) will be planted in a large scale test plot in Brazil to validate productivity.

Oilseed Inventory Study (Unfunded): The USDA is wishing to perform a study that accurately describes the various oil seed crops, their performance, and the rate at which such plants could be scaled up for commercial production.

Large Scale "Regional Solution" Farms Developed (Unfunded): It is anticipated that there will not be one bio-feedstock for world-wide production of biofuel, but there will be multiple solutions, depending on the political-techno and geographic location. Large scale farms are thought to be developed that are suitable for each region of the world.

Swimlane #2: HALOPHYTES
(Salt water tolerant plants that could also yield oil.)

Euphorbia Analysis (In Work): Research into the plant Euphorbia Tirucalli (commonly known as the petroleum plant) for possible development as a feedstock for biofuels. The plant is undergoing preliminary evaluation for its salt water tolerance and is being grown in desert areas.

Salicornia Analysis (In Work): A life cycle analysis of the Salicornia plant, which produces both food and fuel. Development work is primarily being conducted by Global Seawater Foundation.

Seashore Mallow Analysis (In Work): Seashore mallow could fill a niche as a biofuel feedstock as the plant's architecture and oil yield are similar to soybeans. Perhaps even more appealing, is that the plant thrives in salty soils where nothing else will grow. In fact, the plant can be irrigated with saltwater. Limited research is under way to evaluate this crop for North American applications.

Halophyte Assessment (In Work): An analysis of various halophytes for their potential to produce bio-oils in various parts of the world and the scale up potential. Various research organizations are conducting work on specific varieties, but a coordinated assessment effort is needed to bring all the results together for analysis.

Euphorbia Prototype Plots (Unfunded): Larger scale test plots of various plants to verify the yield per acre under various growing conditions.

Optimized Halophytes (Unfunded): Plants that have undergone high throughput nursery breeding techniques to increase their oil level as well as other desirable growing characteristics.

Modified Halophyte Prototype Plots (Unfunded): Larger scale test plots of the above plants to verify growth rates and oil yield.

Large Scale Halophyte Farms Developed (Unfunded): Commercialization of the above modified Halophyte plants.

GMO Halophyte test plot (Unfunded): Genetically modified versions of the above halophyte plants to specifically further improve its oil yield.

8 Tons Salicornia Oil (Unfunded): Expected bio-oil output of large scale test farms, such as Global Seawater Foundation.

Swimlane #3: ALGAE
(Macro & Micro salt and fresh water organisms having oil content)

Cyanobacteria Study (In Work): A study to evaluate if cyanobacteria, which are faster growing and hardier than algae, can be genetically modified to produce oil and grown in photobioreactors to economically produce biofuel.

Dewater Study (In Work): Several researcher are evaluating how to economically separate the small amount of algal biomass (typically < 0.1%) contained in the large amount of water (>99.9%) used for growing.

Oil Extraction (In Work): Research into how to break down the algae cell walls and economically extract oil from various algae strains in a production type setting.

Heavy Metal Removal (In Work): Ways to economically remove the heavy metals that can be found in algae grown in waster water and/or with coal flue gas. These metals would poison the fuel processing catalysts used at fuel refineries.

DOE Algae Roadmap (In Work): DOE is developing an algae biofuels roadmap. Draft expected to be completed for intra-government review in Fall 2009.

Algae Strain Study (In Work): Of the 40,000 different algal strains that are believed to exist in the world, research the additional strains (beyond the 3,000 varieties) that were studied in the Aquatic Species Program.

Algae Demo Plants (In Work): Numerous scaled algae demonstration plants are claimed to be in development around the world. Seambiotic, in Israel, is one such prototype plant known to be currently producing algae using flue gas.

Cost of Algae Study (Unfunded): A detailed economic study to assess the economic viability of algae to compete with fossil fuels. It is believe that an integrated production approach, that also utilizes valuable algae co-products, will be required.

Light & CO_2 level study (Unfunded): Some previous work has been performed on limited algal strains to assess their growth characteristics under varying light and CO_2 levels, but more studies would be required for the optimal algae strains yet to be discovered.

GMO Cyanobacteria Study (Unfunded): A more in-depth study (from above) to evaluate the probability and cost of developing a genetically modified cyanobacteria that has oil producing characteristics.

Results from DARPA project (In Work): The goal of this multi-million dollar program (BAA 08-07) is to develop the technical capability and commercial experience to produce an affordable JP-8 (i.e. military version of commercial Jet-A fuel) surrogate fuel from algae.

USDA algae funding report (Unfunded): A report summarizing the R&D taking place for algae.

New Algae Techs Ready (Unfunded): The assumed breakthrough technologies are developed to address the: optimal algal strains, dewatering, harvesting and oil extraction challenges that remain for this technology to become economically competitive with fossil fuels.

Cyanobacteria Scaled Demo (Unfunded): A scaled demonstration version of the GMO cyanobacteria that was developed (see above.)

GMO Algae (Unfunded): Genetically modified algae organisms are developed that have: much higher oil content, resistance to invading algae species and grazers, higher productivity, high culture stability and auto-bioflocculation tendencies.

Large Scale Algae Plants Developed (Unfunded): After the technical and economic breakthroughs are achieved, it is envisioned that vary large scale algal farms will be developed to start commercial operation of algae oil for biofuel.

Cyanobacteria Plant Developed (Unfunded): If the GMO cyanobacteria can be developed, economically produced and is socially acceptable, it is envisioned that this hardier and higher productivity organism may displace algae as the main oil producing biofeedstock.

Swimlane #4: CELLULOSE FEEDSTOCKS

Billion Ton Study (Completed): Report conducted by DOE's Oak Ridge National Lab (ORNL) on "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The

Technical Feasibility of a Billion-Ton Annual Supply." It showed that 1.3B tons/year of biomass could be harvested to meet 1/3 of U.S. fuel needs by 2030.

BCIWG Report (In Work): The Biomass R & D Board Biomass Conversion Interagency Working Group (BCIWG). The Biomass Research and Development Board established an interagency working group to guide the exploration of cost effective commercially viable processes for converting cullulosic and other biomass to biofuels (ethanol, higher alcohols, and green gasoline, diesel, and aviation fuels.) The group is comprised of NSF, DOE, USDA, EPA and DOD and other agencies. The BCIWG is authoring a 10 year Federal RD&D biomass conversion plan report.

Cellulose to biojet flight demo (not funded): A flight demonstration of a biojet fuel made from cellulose via enzymatic deconstruction and synthetic biology buildup of pure hydrocarbon molecules (alkanes.)

Cellulosic Ethanol becomes cost competitive (funded): A (hoped for) milestone where sufficient R&D has overcome the cost hurdles in making commercial ethanol production less expensive when using a cellulosic conversion processes versus the conventional corn starch method.

Cellulose to biojet demo plant via pyrolysis (not funded): A small demonstration plant that more efficiently converts cellulosic material into a bio-crude oil that can then be fed into conventional oil refineries for processing.

Cellulose/Sugar/Algae Prototype Demo (not funded): Sugars that are derived from hemicellulose from woody plants can be used as nutrients to rapidly grow algae in non-sunlight reactors (i.e. heterotrophic conditions.) Heterotrophic growth of algae on pentose sugars from hemicellulose may be a promising approach for algae production as it would not compete with either food sugar or ethanol sugars, which are all hexose sugars.

Large scale cellulose farms (not funded): Initial commercialization of prairie grasslands that are (no till) seeded with switchgrass and harvested with no environmental damage.

GMO plants for easy sugar conversion (in work): Genetically modified plants, such as poplar trees, that have enhanced growth characteristics such that processing enzymes may more easily break down the lignin for conversion into sugars

Swimlane #5: OTHER FEEDSTOCKS
(All other plants not covered above.)

DOE's CBTL study done (In Work): A Coal & Biomass To Liquid (CBTL) study where biomass is used to offset CO_2 emissions that would normally be environmentally prohibitive in a conventional Coal To Liquid (CTL) fuel production plant.

Revise EISA to include biomass credit (In Work): The present Energy Independence Security Act (EISA) presently does give environmental credit for using some types of biofeedstocks in certain fuel processing methodologies (e.g. bio-oil used in an oil refinery to make a biofuel/fossil fuel mixture.)

Overall Feedstock Assessment (Unfunded): A study to evaluate all other known types of bio-feedstocks (e.g. switchgrass to alkane hydrocarbons through synthetic biology) that could be used to produce biofuel for aviation.

Various Scaled Test Plots (Unfunded): The growing of emerging bio-feedstocks (see above) that could be used for biojet fuel.

Terra Preta Test Plot for CBTL (Unfunded): A scaled agricultural project where the excess solid carbon from the CBTL process is buried in farm plots to evaluate the effect on crop production.

DOE's CBTL & Algae Demos Done (Unfunded): A NETL demonstration project with APS (Arizona Public Supply) where coal is gasified for power generation and algae are grown with flue gas effluent to capture and utilize the CO_2.

Large Scale Cellulose Farms for synthetic biofuel & CBTL (Unfunded): After the fuel processing technologies are developed that can economically convert cellulose into biofuels, it is envisioned that large scale (prairie?) farms will be developed to grow cellulose (e.g. switchgrass, etc.)

Swimlane #5: OTHER
(Primarily activities to coordinate with)

CAAFI biofeedstock roadmap (Done): This roadmap which was developed on January 27th in Dayton, Ohio by 80 representatives from the aviation, biofuel and feedstock industries.

USDA Feedstock Roadmap (Unknown): It is thought that the USDA should develop its own feedstock R&D roadmap, which would include recommendations from this feedstock roadmap.

USDA Feedstock Rankings and R&D Plan (Unknown): Once the roadmap is developed, funding should be secured for future projects that are underfunded or unfunded, based on their ranked importance to provide biofuel feedstocks for aviation as well as ground transportation. The R&D plan will lay out a formula to achieve US energy independence with help from carbon neutral biofuels.

USDA Advanced Biofuel Summary (Unfunded): A final summary report published by the USDA reviewing all of the next generation feedstocks that could be used for making biofuel and making recommendations.