WORKSHOP ON MANUFACTURING SCIENCE NEEDS

12TH JOCG CONTINUOUS MIXER AND EXTRUDER USERS GROUP MEETING

October 30, 2002

A strategic plan is being developed which proposes an initiative in response to studies which point to an urgent Navy need to develop advanced weapons systems to counter the changing world situation. Critical to rapid development and acquisition of these weapons systems is the ability to manufacture and load energetic materials into warheads and propulsion systems. These include underwater weapons, surface weapons, air weapons, and land attack weapons. With the advent of a new generation of energetic materials on the horizon, an S&T strategy is required to ensure the requisite manufacturing approaches are addressed in parallel to the development of these materials. This strategic plan is being undertaken by the Indian Head Division of the Naval Surface Warfare Center because of its responsibility to the Navy as the National Center for Energetics.

The primary purpose of Navy energetics manufacturing is to meet the needs of the Fleet. These are:

- Provide the Navy with operationally superior and affordable platforms and ordnance;
- Align energetics development time with acquisition cycles and performance goals;
- Reduce NAVSEA infrastructure costs while enhancing capability;
- Develop and manufacture explosives with reduced safety footprints**.**

There have been several studies in the last few years that point to a pressing national need for advances in the manufacture of energetic materials. Primary of these is a Navy Studies Board report of 2000, which indicates the direction the Navy will take in the 2000-2035 timeframe, and the role advancing technology will play in this change. These studies indicate the need for weapons with improved performance, but that are also safe and affordable. Additionally, and perhaps of equal importance, are the cost savings resulting from simplified ship design and logistics procedures that can also be achieved by the development and use of extremely insensitive (class 1.6) explosives and propellants.

A recent example of the multidimensional impact of such materials is the “thermobaric explosive”. This material, while producing unique and highly lethal damage mechanisms against underground targets, will also have far reaching implications for the fleet due to its extremely insensitive nature. Fortunately, this material can be produced by current methods. However, many of the materials in the S&T pipeline will require new manufacturing methods.

The purpose of this initiative will be to develop physics-based computer programs and analytic methods for application to explosives and propellants manufacturing. Tools such as Indian Head Division, NSWC’s continuous twin-screw processing facilities will be used as the initial test bed to provide data on which to validate these codes and analysis tools. Of particular interest are models for predicting material states both within and without the extruders, such as flow, temperature, and viscosity.

Known deficiencies in the science and technology of manufacturing energetic materials will be identified. A series of workshops, of which this is the first, will be held where deficiencies will be identified and solutions proposed. From these workshops an S&T program will be formulated.

The deliverables to the Navy will be a set of validated computer codes and analytic tools that can be utilized to manufacture energetic materials that are of high performance, yet are cost effective and safe. This will result in increased mission capabilities, reduced sorties, increased loadout or smaller magazines, reduced logistics cost, and reduced fraticide.

The Manufacturing Science Workshop objective is to identify physics based modeling requirements to implement the next generation of energetics quicker, safer, cheaper and better. The workshop consisted of a panel discussion followed by working group brainstorming to identify research objectives . The panel members were:

Dr. Judah Goldwasser	The Office of Naval Research
Dr. Dilhan Kalyon	The Highly Filled Materials Institute of Steven's Institute of Technology
Mr. John Brough	Navy's Energetics Manufacturing Technology Center
Dr. Davinder Anand	Center for Energetic Concepts Development (CECD)
Mr. Steven Rosenberg	US Army Manufacturing Technology Director, TACOM-ARDEC

Each panel member was given 5 to 10 minutes to talk about their thoughts on the workshop objective. The workshop then broke up into smaller groups to discuss four topics: feed systems, twin-screw processor, process control and safety. There were six groups (there were two groups each for feed systems & twin-screw processor). Each group was given 10 to 15 minutes to report back to the audience on the research objectives identified by their group. A summary of the research objectives identified by each group follows.

1. Feed Systems

MEMBERS:

Gallant, Mitch (NSWC, IHDIV)
Johnson, Sharperson (NSWC, IHDIV)
Budd, Jason (NSWC, IHDIV)
Campbell, Jeff (NSWC, Crane)
Cassell, Elbert (ATK, Radford)
Hall, Adam (ATK, Radford)
Jacobsen, Jason (Autoliv ASP)
Mullarkey, Tom (Coperion)
Nock, Lori (NSWC, IHDIV)
Phillips, Don (D. E. Phillips Associates, Inc.)

BRAINSTORMING ITEMS:

Setpoint tracking – performance
Low dosing rates
Tolerance specification
- Performance

Multiple feeder performance (as a system)
Quality of end-product – ingredient variation
Liquid feed under pressure
Feeding location (how to choose)
Order of addition

Issue: On-line Analysis

Quality maintenance of premixes (shelf-life)
What is important to measure (property correlation to end product property)
Impact of feeder performance on end product
- How to measure/correlate

Understanding movement of solid beds (no tools to understand or we aren't using what is available)
- Flow
- Segregation
- How long do we blend solids for good preblends

Better Standardized (Best Practices) for feeder accuracy determination
- "Every morning"
- Methods used
- Is there a need to standardize
- Time scale to use?
- Statistics to use?

Microprocess based controllers for feedback
- Don't use that information
- Not sure if we trust it
- Are we using controllers as much as we should---feedback

Correlation

Verification of controller

- Loss in weight performance
- During operations (while extruder is running)

Handling of exotic materials (need to get smarter about these materials and how to make them come out of feeders well)

- The Nanos
- High surface area
- Low bulk density
- Hygroscopic
- Air sensitive

How do we design sealed feed systems for air sensitive materials (follow users of clay)

Solid Bed Dynamics

- Simulate flow of beds
- Experiment w/ colored beads
- Moisture effects

Liquid injection: to pressurize or not and why (is there a smart way to do this)

2. Twin-Screw Processor

MEMBERS:

Newton, Bill (NSWC, IHDIV)
Bruck, Hugh (UMCP)
Chan, Tung (ATK, Radford)
Coles-Cieply, Tinya (NSWC, IHDIV)
Graybill, Jim (MPRI)
Harte, Michael (Autoliv)
Kowalczyk, Jim (Shear Tool, Inc.)
Liakos, Tas (USNA)
Maller, Gilles (Clextral)
Murphy, Connie (NSWC, IHDIV)
Zeigler, Hays (ATK, Radford)

BRAINSTORMING ITEMS:

Modeling

- Flow Distribution, retention time (existing, good higher level)
- Need microstructural details for complex fluids
- Computational limitations
- Don't have a good model – problems trying to scale-up the process
- Scale-up effects
- Important physical characteristics (dependence on location in extruder)
- Understand characteristics of <u>different</u> materials in extruder (different materials --- different outputs)
- A number of empirical studies exist for most conventional materials
- Modeling used more for <u>higher end</u> applications
- Develop tool for screw configuration applicable to new materials
- Thermal, pressure, time dependence of formulations
- Work-intensive process to characterize material and extruder performance
- Database exists of material characteristics for a variety of materials (rheology, temperature dependence)
- Trouble with high solids loading of material
- Difficult to extend extruder performance from one material to another
- Nanomaterials are not understood at all
- Reaction modeling in extruder exists, but proprietary
- Complex fluids require more specialized configurations
- Unitary feed vs. multiple feed
- Depends on application (if modeling is important); higher end applications need models (dog food vs. explosives)

What areas of extruder research are required for research

- Characterize materials, end product
- Which characteristics (crystal structure, interfacial energies, particle fracture strength)
- Extruder process of function of geometry, time
- Feed control problems (taken care of by back mixing)
- Understanding variations are important near limits of extruder capability

- Emphasize new formulations that cannon be made in batch processes (better surface area/volume ratio for TSE)
- Chemistry model (reaction kinetics, what is location dependence)
- Brute force approaches can also resolve problems
- 92% limit on solids loading (why?)
- Model localized effects (T,P) in extruder
- Break up extruder into sections by functionality
- What happens to long-chain polymer in mixing process

Models that can be used by process engineers or by expert

- User-friendly, built-in databases
- Interactive?
- Interface with control systems
- Real-time capabilities
- Simple and idiot proof for technicians
- Need to get macroscopic parameters (T,N,Q,P)
- Diagnostic technologies
- Commercial codes can be used to develop an approximate idea of TSE Process

Summary

- Industry does not worry about same things as government (brute force vs. science)
- User-Friendly models and codes
- Codes than can model solid/fluid transition in extruder

3. Safety

MEMBERS:

Thomas, Wayne (NSWC, IHDIV)
Richman, Stuart (NSWC, IHDIV)
Gevgilili, Halil (SIT)
Goldwasser, Judah (ONR)
Kavetsky, Bob (ONR)
Kalyon, Dilhan (SIT)
Newell, Jason (Takata, Inc.)
Nuckols, Rich (IHDIV, NSWC)
Rentfrow, Dick (ATK, Radford)

BRAINSTORMING ITEMS:

How do we correlate basic safety data to what is happening in the TSE?

- Build an initiator tester (A practical test) that profiles different materials (shear rate, temp, etc.)

What are the local pressures, friction, temps, inside the extruder to be able to correlate to the existing safety database

Build a disposable test (device) fixture where you can run a condition until an initiation occurs (formulations, solids, loading, etc.)

- deformation rate
- temperature
- stress

<u>3-Generations</u>
Bulk
Local
Model

Build a failure envelope defined by the function of stress, def. rate, temp, residence time

Develop a reliable initiation model based on shock, shear

Exchange information among all of industry (not just energetics) fundamentals that are common to all

How can you predict & measure when mechanical failure is going to occur? An interactive device.

Establish better exchange/sharing of information between users

- identify problem areas
- couple with fundamentals

Urgent Question: What are the conditions which give rise to initiation?

- Long-term solutions
- Short-term solutions

Long-term Solutions

- Basic Science
- Applied Science
- Engineering

*Communicate with Conventional Testing & Data

*Academicians & Industry
- other industries

- Don't even understand initiation mechanisms --- need that input from others

Short-term Solutions

- Build/use “initiation tool”
  - predictable dynamics & heat transfer
  - disposable screw elements
  - use for new formulations or changes in formulations
  - Couple to existing mathematical models
- Better communication

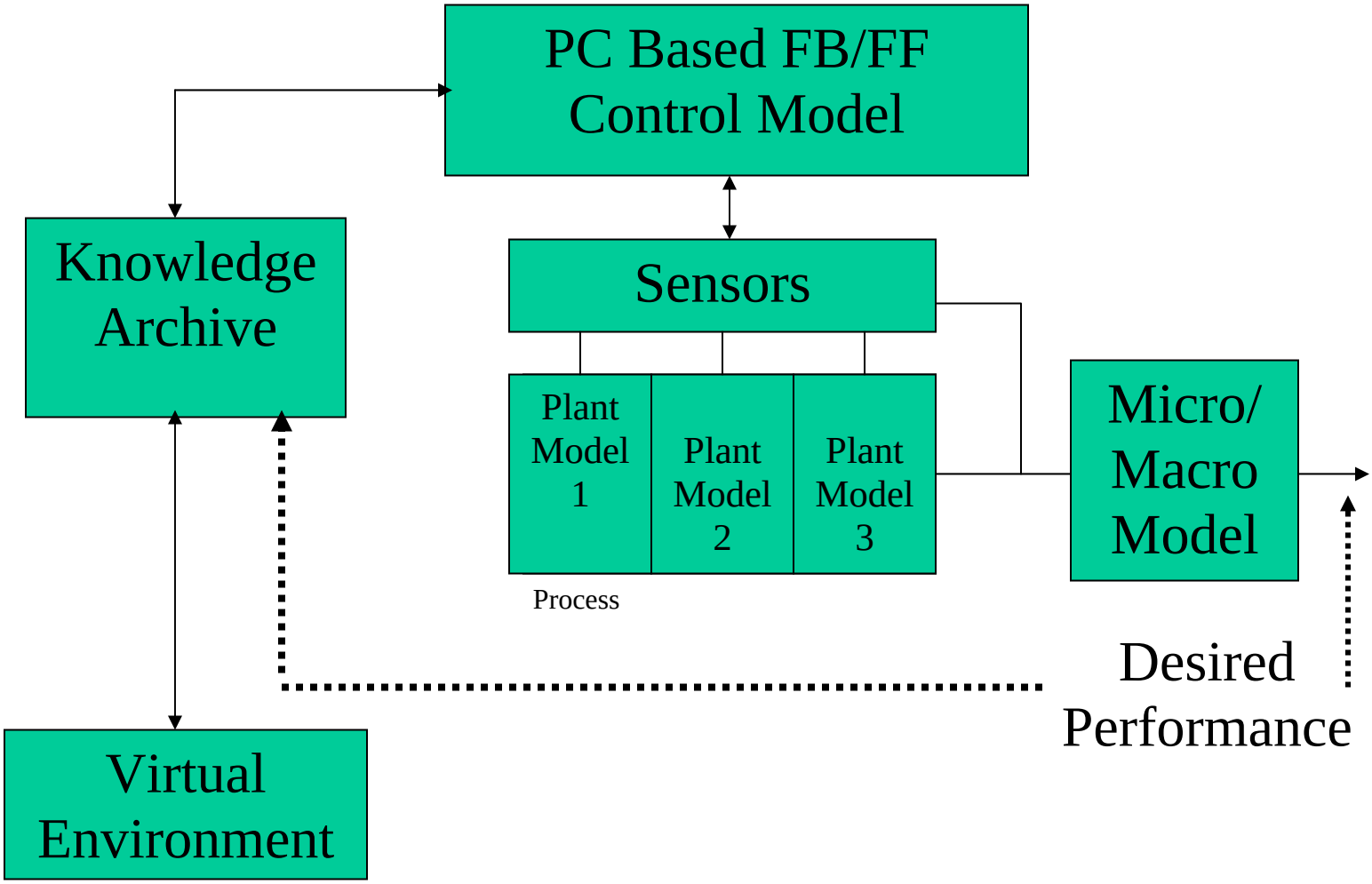
  *Website @ SIT

4. Process Control

MEMBERS:

Muscato, Rich (NSWC, IHDIV)
Gonzales, Chris (NSWC, IHDIV)
Anand, Davinder (CECD)
Bigio, David (UMCP)
Liu, Edmund (Aerojet)
Meyer, Erik (NSWC, IHDIV)
Mudalamane, Rajath (UMCP)
Rosenberg, Steve (TACOM-ARDEC)
Sabbagh, Adel (UMCP)

BRAINSTORMING ITEMS:



- Application of Artificial Intelligence
- RTD
- Modeled Based Control
- Response Time

5. Feed Systems

MEMBERS:

Rose, Mike (ATK-Thiokol)
Stevenson, Brad (NSWC, Crane)
Dawag, Timothy (TACOM-ARDEC)
Elkouss, Paul (UMCP)
Kovats, Andy (Brabender Technolgie, Inc.)
Mishra, Indu (CPIA-JHU)
Mosier, Terry (Goodrich)
Natt och Dag, Mats (Nexplo Bofors, Inc.)

BRAINSTORMING ITEMS:

1. Gram Level
   Feed window should be established early
   Depends on material being fed
   Formulators need accuracy info

Modeling Required:

Particle size
Flowability
Rates
Screw designs/req. screws for material (Material Database=screws)

2. Full up feeder study – collect samples periodically and determine particle size distribution
   - Is feeder agitation enough to stop segregation?
3. Particle size could/does affect extruder conditions (ie. Torque)
   Post process burn rate testing
   Feeder conditions, monitor screw speed
   Material bridging/Agglomerating
4. Properties of material
   - humidity control/level (too low or too high)
   - raw material preparation
5. LIW Feeders
   - Depends on how well you calibrate feeder
   - Full up feeder study and compare collected data to feeder data

CONCLUSIONS:

Modeling would help
-screw design
-segregation & agitation
Formulators need accurate information
Calibration Process

6. Twin-Screw Processor

MEMBERS:

Jasinkiewicz, Kristin (TACOM-ARDEC)
King, Roderick (TACOM-ARDEC)
Chernoff, Martin (NSWC, IHDIV)
Fishbein, Leslie (TACOM-ARDEC)
Brough, John (NSWC, IHDIV)
Creegan, Rick (B&P Process Equipment)
Philippe, Penel (Clextral SAS)
Mielcarek, Dan (Coperion)

BRAINSTORMING ITEMS:

Modeling Physics
Plant Design:
- Data acquisition vs. cost
- Screw design, feeds, speeds, temperatures, die design

Scale Up Issues (20 mm, 40mm, 100mm)
Payoffs: data transfer, not paying all of 90% over capability in peace, reduced development time
Privatize Surge Capacity Costs

Help fund new Explosion Proof Sausage Facility?
- Fund flexible manufacturing plants
- Multi-energetics capability with/existing production

So much data to acquire for costly models….suggest defining important, smaller models to develop & coordination of efforts of data acquisition. Perhaps a steering committee.