UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

October 27, 1995

APPLICANT: Westinghouse Electric Corporation

PROJECT: AP600

SUBJECT: SUMMARY OF MEETING TO DISCUSS MODIFICATIONS TO THE NOTRUMP COMPUTER CODE FOR AP600 APPLICATION

The subject meeting was held on October 12, 1995, in the Westinghouse Electric Corporation's Rockville, Maryland office between representatives of Westinghouse and the Nuclear Regulatory Commission (NRC) staff. The purpose of the meeting was to address staff questions and concerns related to modification of the NOTRUMP small break LOCA computer code which were made for validating AP600 test results. These concerns were raised in followon questions submitted to Westinghouse in a letter from the NRC dated September 22, 1995.

According to Westinghouse, changes to the approved, operating plants, version of NOTRUMP were necessary to get the code to run to completion when being used to predict AP600 test results. The approved version of NOTRUMP, when modelled for AP600 systems, can not adequately handle the low pressure conditions encountered in AP600 design basis accident scenarios. Although the changes appear substantial, they have minimal impact on the central numerics of the code. Westinghouse provided comparison of SBLOCA analyses on two operating plants using the approved version and the modified version of NOTRUMP to demonstrate that the results were virtually identical. Westinghouse emphasized that the subject modifications have been made to the NOTRUMP code for AP600 purposes only and have not been applied to any operating plant for official analyses. In addition, all AP600 SSAR analyses performed in the recent Chapter 15 draft submittal were accomplished with the modified version of NOTRUMP.

Each of the code changes or model modifications to NOTRUMP was reviewed. It was noted that although the Moody correlation was used for critical flow calculations from the break as required by 10 CFR Part 50 appendix K, Henry-Fauske and HEM were used to model critical flow from the ADS valves. The NRC staff questioned whether this was the intent of the regulation since ADS is simply a system designed break. The staff stated that they would review how critical flow is treated in BWR ADS analysis. Additionally, the staff discussed the horizontal stratified flow model. This is a key model for determining timing of CMT draindown and ADS actuation. Westinghouse will need to thoroughly explain and document the basis for this model in their response on this NOTRUMP change.

Other questions from the staff included:

a. Concerns about friction modelling in counter-current flow conditions.

b. Concerns that hot leg S/G reflux flow does not obey conservation of momentum equations.

c. Lack of benchmarking of two phase level swell predictions by code with test data.

The eighteen NOTRUMP model changes documented in the staff's RAI's were individually reviewed to ensure that the intent was understood and to obtain clarification where appropriate. Westinghouse agreed to answer all eighteen of these RAI's and, subsequent to their responses, have another meeting to discuss how to proceed with the remaining NOTRUMP preliminary V&V RAI's.

The staff and Westinghouse also agreed to the following steps for obtaining a supplemental DSER on the NOTRUMP code:

1. Respond to prioritized Code Applicability Document RAI's.

2. Provide detailed documentation of the modifications to NOTRUMP for AP600 application.

3. Provide qualification for NOTRUMP modelling (Should already be done in Preliminary Verification and Validation Reports).

4. Respond to prioritized RAI's on PV&V's (CMT; ADS; OSU; & SPES).

5. Answer RAI's generated by item (2).

6. Answer any additional RAI's generated by responses to item (4).

Attachment 1 is the list of meeting attendees. Attachment 2 are the handouts provided by Westinghouse during the meeting.

original signed by:

William C. Huffman, Project Manager
Standardization Project Directorate
Division of Reactor Program Management
Office Of Nuclear Reactor Regulation

Docket No. 52-003

Attachments: As stated

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| DATE | 10/19/95 | | 10/24/95 | | 10/27/95 | | | |

b. Concerns that hot leg S/G reflux flow does not obey conservation of momentum equations.

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William C. Huffman, Project Manager
Standardization Project Directorate
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cc w/attachments:
See next page

## WESTINGHOUSE/NRC MEETING
## ON NOTRUMP COMPUTER CODE MODIFICATIONS
## OCTOBER 12, 1995

### MEETING ATTENDEES

| NAME | ORGANIZATION |
|---|---|
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| Larry Hochreiter | Westinghouse |
| Phil Meyer | Westinghouse |
| Earl Novendstern | Westinghouse |
| Brian McIntyre | Westinghouse |
| Ralph Landry | NRC |
| Tim Collins | NRC |
| Bill Huffman | NRC |
| Paul Boehnert | NRC |
| Novak Zuber | NRC Consultant |
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010109

DF03

AP600

# NOTRUMP OVERVIEW

Phil Meyer
Software Technology Development

Attachment 2

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**History**

Original Version Started In 1975; Finished In 1977

- General Code But Primarily Aimed At Steam Generator Secondary Side Analyses
    - o Equilibrium Two-Region Fluid Nodes
    - o Primary-To-Secondary Heat Transfer
    - o Separator Models
    - o Two-Phase Natural Circulation Capability
- WCAP-9236 (-9237): "NOTRUMP A Nodal Transient Steam Generator And General Network Code" (February 1978)

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**History (cont.)**

Revised Version Started In 1978; Finished In 1979

- Better Estimate Calculations
  - o Demonstrating Natural Circulation Modes
  - o Inadequate Core Cooling Studies
- Models Added
  - o Break Flow Models
  - o Node Stacking And Mixture Level Tracking Model
  - o Horizontal Stratified Flow Model
- Used For TMI-2 Natural Circulation Studies (May 1979)
- WCAP-10076 (-10077): "NOTRUMP, A Nodal Transient General Network Code" (March 1982)

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**History (Cont.)**

- o SBLOCA Version Started In 1980; Approved By NRC On May 21, 1985
  - Addressed Post-TMI Requirements
    - o NUREG-0611
    - o NUREG-0737 (Particularly Sections II.K.3.30 Of Enclosure 3)
  - WOG Elected To Reference NOTRUMP As Their Licensing SBLOCA Model
  - Modifications Made
    - o Non-Equilibrium Equations And Solution Techniques
    - o Fluid Equations Of State Generalized For Non-Equilibrium Nodes

## OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**History (Cont.)**

- o SBLOCA Version Started In 1980; Approved By NRC On May 21, 1985
  - Models Added
    - o Pump Model
    - o Core Model
    - o Accumulator Model
    - o Interfacial Mass An Energy Transfer Model
    - o New Drift Flux Correlations
    - o Flooding Model
  - WCAP-10079-P-A (-10080-A): "NOTRUMP, A Nodal Transient Small Break And General Network Code (August 1985)
  - WCAP-10054-P-A(-10081-A): "Westinghouse Small Break ECCS Evaluation Model Using The NOTRUMP Code (August 1985)
  - WCAP-10054-P-A Addendum 1 (-10081-A Addendum 1): "Addendum To The Westinghouse Small Break ECCS Evaluation Model Using The NOTRUMP Code For The Combination Engineering NSSS" (March 1987)

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**Base (1985 EM) Code Description**

- o Functional Requirements (Section 1 Of WCAP-10079-P-A)
  - Momentum Balance Suitable For Time Dependent Flows
  - Two-Phase Flow Capabilities
    - o Natural And Mechanical Phase Separation Models
    - o Countercurrent Flow Models
    - o Mixture Level Models
  - Thermal Non-Equilibrium Models
    - o Interfacial Heat And Mass Transfer, Condensation, And Evaporation
    - o Bubble Rise And Droplet Fall
  - Temporal And Spatial Boundary Conditions
  - Sufficient Detail To Model Regions Or Components And Physical Processes

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**Base (1985 EM) Code Description (Cont.)**

- o Addresses Post-TMI Requirements (Enclosure 2 Of SER In WCAP-10079-P-A)
  - Confirm Adequacy Of Core Heat Transfer And Level During Core Uncovery Conditions
  - Validate Adequacy Of Modeling SG Primary Side As Homogeneous Mixture
  - Validate Condensation Model
  - Demonstrate Adequacy To Calculate Flashing During Depressurization
  - Validate Coefficient Used in Accumulator Model
  - Validate With LOFT L3-1 And L3-7 And Semiscale S-UT-08

## OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**Base (1985 EM) Code Description (Cont.)**

- o Code Components (Section 2-1 of WCAP-10079-P-A)
- o NOTRUMP Implicit Method (Sections 2-2, 8 and Appendix E of WCAP-10079-P-A)
- o Specific Models (WCAP-10079-P-A)
  - Non-Equilibrium Pressure Search (Appendix L)
  - Interfacial Mass And Energy Transfer Model (Appendix V)
  - Bubble Rise/Droplet Fall (Appendix H)
  - Node Stacking And Mixture Level Tracking Model (Appendix N)
  - Accumulator Model (Appendix R)
  - Friction And Elevation Pressure Drop (Section 5)
  - Flow Partitioning (Appendix F)
  - Drift Flux Model (Appendix G)
  - Flooding Model (Appendix W)
  - Horizontal Stratified Flow Model (Appendix O)
  - Break Flow Models (Appendix M)
  - Pump Model (Appendix P)
  - Heat Transfer (Section 6)
  - Core Nodes (Section 7 And Appendix T)
  - Time Step Selection (Section 10)

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**Application Of Base Code To SBLOCA (WCAP-10054-P-A)**

- Small Break Modeling Using NOTRUMP (Section 3)
  - Core/Vessel Model
  - Loop Model
  - Safety Injection Nonequilibrium Mode Description
  - Steam Generator Model

- Sensitivity Analyses (Section 6)
  - Noding Sensitivity Of Loop Seal Model (N/A To AP600)
  - Core Noding Sensitivity Study (Section 6-2-1)
    - 12-Node Versus 4-Node Core Model
    - 4-Node Core Model Shown To Be Adequate
  - Steam Generator Noding Sensitivity Study (Section 6-3-1)
    - Primary Noding: 8 vs 4; 4 Is Adequate
    - Secondary Noding: 4 vs 1; 1 Is Adequate

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

**Application Of Base Code To SBLOCA (WCAP-10054-P-A)**

- o **Analyses**
  - Cold Leg Break Spectrum (Section 5)
  - Breaks at Pressurizer Vapor Space (Section 8)
  - RCP Seal Leak With Small Break LOCA (Section 9)
  - Cold Leg LOCAs With RCPs Running (Section 10)

## OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**Base (1985 EM) Code Validation (WCAP-10054-P-A)**

- o Thermal Hydraulic Test Facilities (THTF) At ORNL (Section 3-1-3)
  - 12 Core Nodes
  - 4 Uncovering Tests (Table 3-1-4)
  - 4 Reflood Tests (Figures 3-1-2 To 3-1-5)

- o Code Verification By Comparison Of Analysis Calculation And Integral Facility Test Data (Section 7)

  - LOFT L3-1 (4" Equivalent CLB) With EM Break Flow
    - o Inner Vessel Mixture Level: Conservative (~2.5 ft.)

  - LOFT L3-1 Using Break Flow Data
    - o Inner Vessel Mixture Level: Conservative (~1 ft.)

  - LOFT L3-7 (1" Equivalent CLB) Using Break Flow Data
    - o Good Agreement: Pressure And LP Temperature

  - Semiscale Test S-UT-08 (5% CLB) With Break Flow Data
    - o Collapsed Core Level (Figure 7-3-12)
    - o Good Agreement; Predicts The Deep Pre-Loop Seal Clearing Uncovery

# OVERVIEW OF NOTRUMP CODE, APPLICATIONS, AND VALIDATION

AP600

**Conclusions**

- NOTRUMP Was Specifically Developed And Validated As A SBLOCA Code To Capture The Following Phenomena:
  - Two-Phase Forced And Natural Circulation
  - Two-Phase Mixture Level Behavior
  - Horizontal Two-Phase Flow
  - Core And Steam Generator Heat Transfer
  - Critical Flow

- NOTRUMP Has The Capability To Model AP600 SBLOCA Phenomena
  - Specific Improvements Made For Low Pressure Application
  - Validation Of These Improvements Is In Progress

AP600

# CODE VALIDATION PROCESS

L. E. Hochreiter
Nuclear Safety Analysis

# NOTRUMP Code Validation

AP600

**BACKGROUND**

We have been following the code validation process steps, outlined in letter ET-NRC-93-3976, based on meeting with Dr. McPherson of the NRC. The basic steps include:

1.) Identification Baseline Computer Models Used For The 1992 SSAR Calculations

- o NOTRUMP Was Identified For SBLOCA
- o NOTRUMP CAD Issued

2.) Test Analysis/Computer Code Validation

- o This Process Has Been On-Going For NOTRUMP
- o CMT, OSU, SPES, ADS Preliminary Validation Reports Have Been Issued
- o NOTRUMP Model Changes Have Been Identified Based On Preliminary V&V Reports

3.) Blind Test Predictions

- o NOTRUMP Blind Test Predictions Were Submitted To NRC
- o After Data Was Released, Blind Test Comparisons Were Provided

# NOTRUMP Code Validation

AP600

**Background (continued)**

4.) Evaluation Of Blind Test Prediction

- o Currently In Progress Along With Resolution Of The RAIs On Preliminary Reports, Will Be Included In Final V&V Report

5.) Computer Code Model Update (If Necessary)

- o Computer Code Model Updates Were Made And Documented In OSU (SPES Preliminary V&V Reports)
- o Any Addition Model Updates (If Needed) Due To RAI Response Will Be Documented In Final V&V Report

6.) Code Validation Report (Final V&V)

- o RAI, Model Resolution Needed First
- o Final Analysis Will Be Performed With Final Version Of The Code

# NOTRUMP CODE VALIDATION - HISTORY

AP600

1992 SSAR Was Performed With the then Current And Approved Version Of The NOTRUMP Code

- o NOTRUMP Was Used As An Appendix K Code (1971 + 20% Decay Heat, Moody Break Flow Model, Etc.)

- o A Realistic Model Was Used For Flow From The ADS Valves (Henry-Fauske + HEM)

- o Difficulties Were Encountered In Running The Plant Cases; The Time Step Which The Code Required Decreased From A Nominal $10^{-3}$ To $10^{-5}$ - $10^{-6}$ seconds per Computational Step Because Of The Low Pressure

- o In Spite Of The Computational Time Required, The Analysis Was Completed

# NOTRUMP CODE VALIDATION - HISTORY

AP600

Difficulties Occurred In 1993 When We Began To Model The SPES And OSU Tests

- The Code Would Essentially Grind To A Halt At Low Pressure ~ 100 Psi and Crash For OSU Calculations
- Plant Calculations, While Having Excessive Run Times, Would Continue To IRWST Injection
- SPES-2 Calculations Showed Similar Difficulties As OSU, But Not As Severe
- Initial Thought Was That The Modeling Was Inconsistent Between Plant, SPES-2, And OSU

# NOTRUMP CODE VALIDATION - HISTORY

- Several Technical Reviews Were Held To:

  o Ensure Consistency Between The Plant And Tests

  o Ensure Consistent Noding, Boundary Conditions

  o Verify The Test Deck Input Relative To The Plant

- Following Correction Of Several Input And Modeling Inconsistencies, Code Performance Difficulties Continued

# NOTRUMP CODE VALIDATION - HISTORY

AP600

We Began To Examine And Improve The Code Models In September 1994

- Changes Were Made As Discussed In The NOTRUMP/OSU-SPES Preliminary Validation Reports, As Per The Code Validation Process, The Changes Resulted In:

  - o Code Able To Perform Equally Well To IRWST Injection For The Plant, OSU And SPES-2

  - o Significant Improvement In Run Time

  - o NOTRUMP Calculations For The Tests Agreed Well With The Test Data For OSU, SPES / CMT (2 Reports) and ADS

- 1995 SSAR Plant Calculations Used The Improved Models, And Confirmed The Conclusions Of The 1992 Calculations

  - o The Worst Break (DEDVI) Did Not Uncover In 1995 Calculations, Due To The Addition Of The DVI Line Venturi

  - o Other Breaks Were Similar

# NOTRUMP REVIEW - STATUS

- Initial Draft INEL Review (October 1993) Of The NOTRUMP Code Identified Some Potential Areas For NOTRUMP Improvement For Low Pressure Applications (Page 4, C.E. Slater Report) Such As:

  - o Condensation In The CWT
  - o Thermal Stratification In CWT, IRWST
  - o Level Tracking
  - o Low Flow Heat Transfer, Pool Boiling
  - o Stratified Flow In Pipes
  - o Wall Heat Transfer
  - o Interfacial Heat And Mass Transfer

# NOTRUMP REVIEW - STATUS

AP600

- In Addition, The NOTRUMP CAD (November 1994) Indicated That Some Code Improvement Would Also Have To Be Made (Sections 3.2, 4.2 and Conclusions)

- In May 1995, Meeting On CAD/RAIs, Model Changes To NOTRUMP Were Briefly Discussed

However, We Apparently Did Not Make It Clear That We Were Making Model Changes, As Needed To Analyze OSU And SPES-2

# NOTRUMP VALIDATION PROCESS

AP600

- To Complete The Validation Of NOTRUMP For The AP600, Westinghouse Will:
  - o Respond To The Code Related RAI's To Obtain Closure On The Code
  - o Respond To The High Priority RAI's On The CAD
- Objective Is To Reach Closure On The Code And Its Models ASAP
- Once Closure Is Reached On The Code And Its Models, The Final Validation Report Will Be Prepared and Submitted To The NRC
  - o We Will Attempt To Close Off The Remaining RAI's on The Preliminary Report In the Final Report
- We Will Review The Final Validation Report Results With The Staff

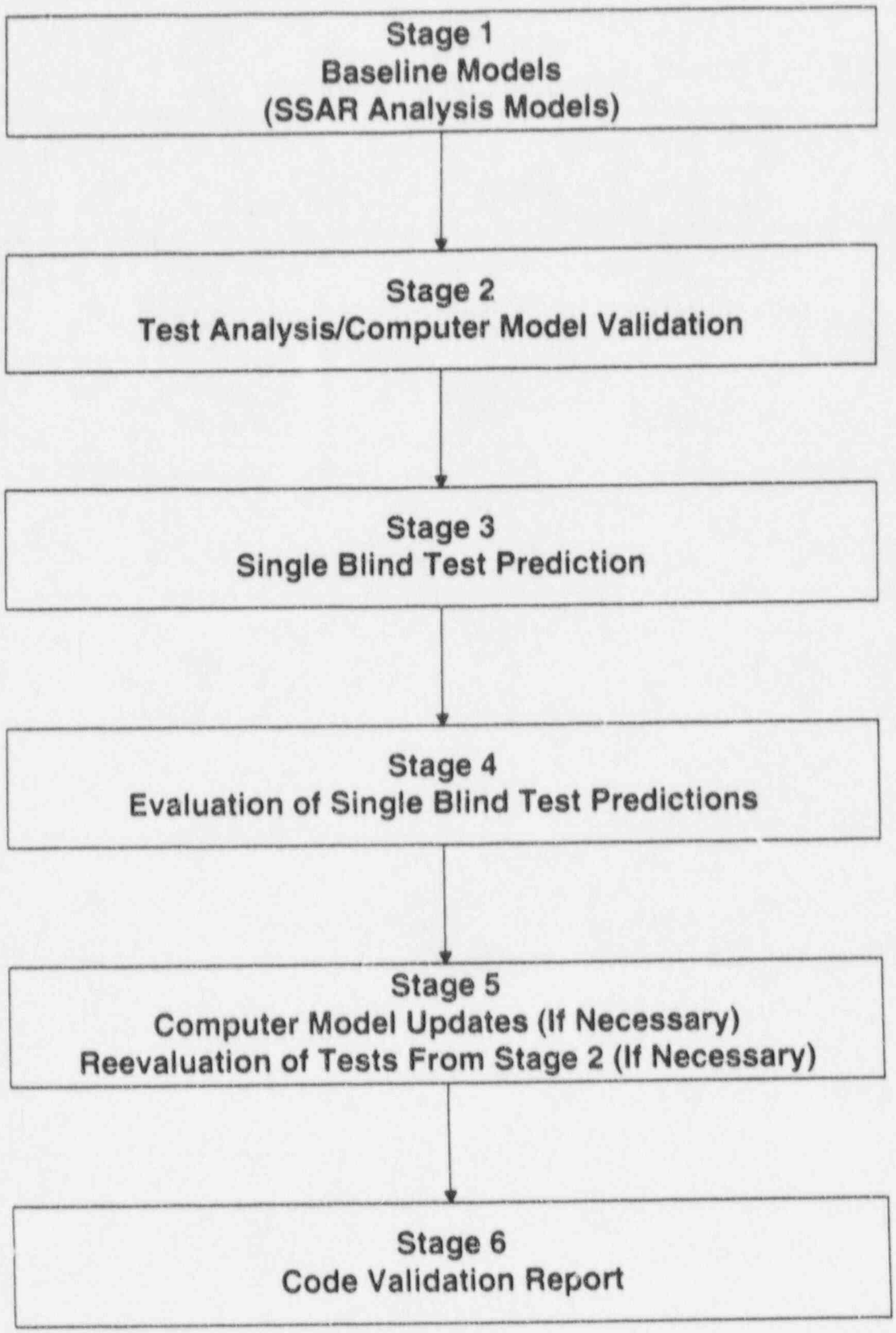



Figure [illegible]. Test Analysis Group, Code Validation Process Steps

# OVERVIEW OF NOTRUMP CODE MODIFICATIONS

Phil Meyer
Software Technology Development

# Overview Of NOTRUMP Model Improvements

- **New Code Model Or Model Modifications**
  - Difficulties Addressed
  - Description of Model or Modification
    - Section 4 of SPES-2 and OSU Preliminary Validation Reports
  - Coding Impact
  - Impact On Results

# New Code Models And Model Modifications

AP600

- **Momentum Equation**
  - Net Volumetric Flow-Based Momentum Equation (NRC Item #3)
  - Implicit Treatment Of Gravitational Head (NRC Item #10)
  - Two Phase Friction Multiplier (NRC Item #17)
  - Pump Model (NRC Item #9)

- **Vertical And Horizontal Two Phase Flow**
  - SIMARC Drift Flux Methodology (NRC Item #1)
  - Modifications To Drift Flux Correlations (NRC Item #2)
  - Revised Horizontal Stratified Flow Model (NRC Item #4)
  - Horizontal Flow Drift Flux Model (Levelizing Model) (NRC Item #11)
  - Contact Coefficients (NRC Item #5)

- **Mixture Levels**
  - Fluid Node Stacking Logic (NRC Item #19)
  - Bubble Rise (NRC Item #8)
  - Region Birthing Logic (NRC Item #12)
  - Mixture Level Overshoot (NRC Item #7)
  - Internally Calculated Liquid Reflux Flow Links (NRC Item #6)

- **Heat Transfer**
  - Condensation (NRC Item #13)
  - Critical Heat Flux (NRC Item #14)
  - Implementation Of Transition Boiling Correlation (NRC Item #20)

- **Critical Flow**
  - Henry-Fauske / HEM Critical Flow Correlation (NRC Item #18)

# Net Volumetric Flow-Based Momentum Equation (3)

AP600

- **Difficulties Addressed**
  - Inability Of Mass Flow Rate To Change Instantaneously With Densities
  - Drift Flux Better When Cast In Terms Of Volumetric Flow
  - Exacerbated By The Low Pressures Of AP600
- **Description Of Modifications**
  - Temporal Derivative Cast In Terms Of Q As State Variables
  - Friction In Terms Of Either W Or Q
  - Central Numerics Easily Modified To Q As State Variable
- **Coding Impact**
  - Minimal Changes To Central Numerics
  - Drift Flux Already Available For Both Mass And Volumetric Flow
- **Impact On Results**
  - Eliminates Above Difficulties
  - Generally More Robust For Two-Phase Flow
  - No Impact on Single-Phase Flow
  - Improves Node Stacking And Mixture Level Tracking Model

# Implicit Treatment Of Gravitational Head (10)

- **Difficulties Addressed**
  - Flow Instabilities Possibly Caused By Explicit Treatment
- **Description Of Modifications**
  - Implicit Implementation Into Central Numerics
    - Change In Gravitational Head Due To Change In Nodal State Variables
- **Coding Impact**
  - Coding Changes
    - Linearizations
    - Incorporation Into Central Numerics
- **Impact On Results**
  - Improves Overall Robustness

# Two Phase Friction Multiplier (17)

- **Difficulties Addressed**
  - Numerical Flow Oscillations
    - Caused By Discontinuity In Quality Used
  - Lower Limit On Pressure of 250 psia
  - Discontinuity At Quality Of 1.0

- **Description Of Modifications**
  - Always Use Static Quality
    - Well-Defined For Both Co-current And Countercurrent Flow
    - Continuous (Due To SIMARC Draft Flux Methodology)
  - Extend Table From 250 psia to 14.7 psia
  - Smooth Transition For Qualities Between 0.9 and 1

- **Coding Impact**
  - Localized Changes (FLOW and F44)

- **Impact On Results**
  - Improves Robustness

# Pump Model (9)

- **Difficulties Addressed**
  - Lack Of Robustness At Low Pressure
  - Can Cause Code To Bomb Even Though Pump Is No Longer An "Actor"

- **Description Of Modifications**
  - Use Inlet Density Model (Already Available)
  - Simpler, more Robust Pressure Discharge Calculation
    - Approximation To Original Calculation
  - No Pump Critical Flow Calculation Performed
    - Not Necessary For SBLOCA

- **Coding Impact**
  - Minimal Coding Changes

- **Impact On Results**
  - Eliminates Above Difficulties
  - Code Runs Without Intervention To Pump Model

# SIMARC Drift Flux Methodology (1)

AP600

- **Difficulties Addressed**
  - Non-Physical Behavior Of Void Propagation Approach
  - Especially Low Void Fraction Above High Void Fraction
  - Exacerbated At Low Pressures

- **Description Of Model**
  - Determine Co-current To Countercurrent Flow Transition Points
  - Compare net Flow To Transition Points
    - Co-current Flow: Use Donor End Of Link
    - Countercurrent Flow: Interpolate Between Transition Points

- **Coding Impact**
  - Applied To Three New Drift Velocity Models
  - Localizing Coding (SIMARC, SIMARCJ, DFLEVL)

- **Impact On Results**
  - Eliminates Above Difficulties
  - Has Appropriate Limits
  - Treats Flooding Naturally

# Modifications To Drift Flux Correlations (2)

AP600

- **Difficulties Addressed**
  - Non-Physical Limits Of Some Correlations
  - Incompatible With SIMARC Drift Flux Methodology
- **Description Of Modifications**
  - Modify Yeh Correlation For Void Fractions Approaching 0.0 and 1.0
  - Modify TRAC-P1 Correlation For Void Fractions Between 0.95 and 1.0
  - Modify (G-64) And (G-65) Of WCAP-10079-P-A
    - Inverse Of Square Root Of Void Fraction
- **Coding Impact**
  - Minimal Coding Changes
- **Impact On Results**
  - Allows Application Of SIMARC Drift Flux Methodology To
    - Yeh Correlation
    - TRAC-P1 Correlation

# Revised Horizontal Stratified Flow Model (4)

AP600

- **Difficulties Addressed**
  - Inability Of Mass Flow Rates To Change Fast Enough

- **Description Of Model**
  - Accounts For Temporal Area And Density Changes
  - Changes In Flow Partitioning

- **Coding Impact**
  - Coding Additions
    - Setting Up Momentum Equations
    - Linearizations In Central Numerics

- **Impact On Results**
  - Reduces Severity Of Above Difficulties
  - Alternative To Original Horizontal Stratified Flow Model

# Horizontal Flow Drift Flux Model (Levelizing Model) (11)

- **Difficulties Addressed**
  - Deficiencies Of Original Horizontal Stratified Flow Model At Low Pressure
  - Possible Problems With Revised Horizontal Flow Model
  - Can Replace Other Models Used For Horizontal Flow

- **Description Of Model**
  - Levelizing Drift Velocity Correlation
  - Uses SIMARC Drift Flux Methodology

- **Coding Impact**
  - Modular (DFLEVL)
  - Drift Velocity Correlation Input Option

- **Impact On Results**
  - More Natural Way To Model Horizontal Flow
  - Alternative To Original And Revised Horizontal Stratified Flow Models

# Contact Coefficients (5)

- **Difficulties Addressed**
  - Regions Cannot Be Formed By Flow Convection

- **Description Of Modifications**
  - KGFL Option Allows Gas To Flow Into Non-Existent Upper Region
  - KFFL Option Allows Liquid To Flow Into Non-Existent Lower Region

- **Coding Impact**
  - Minimal Coding Changes

- **Impact On Results**
  - More Realistic Flow Partitioning For Certain Geometries
  - Can Be Used In Conjunction With Levelizing Model

# Fluid Node Stacking Logic (19)

AP600

- **Difficulties Addressed**
  - Stack Levels Hanging At Node Boundaries
  - Lack Of Robustness
- **Description Of Modifications**
  - Simpler Logic For Volumetric Flow Option
  - New Logic Specifically To Address Levels Hanging
    - Anticipates Whether Draining For Filling
- **Coding Impact**
  - Localized Coding Changes (STACK, FLOW)
  - Logic - Intensive Coding
- **Impact On Results**
  - Minimizes Above Difficulties
  - Works Better With Volumetric Flow
  - Changes Are Not Optional

# Bubble Rise (8)

- **Difficulties Addressed**
  - Courant Limit As Region Becomes Small
  - Bubble Rise Approached Zero As Void Fraction Approached One
  - Bubble Rise Went Negative In Some Circumstances

- **Description Of Modifications**
  - Implicit Implementation Into Central Numerics
  - Upper Limit On Void Fraction For Bubble Rise
  - Zero Lower Limit
  - Analogous Improvements For Droplet Fall

- **Coding Impact**
  - Coding Changes In Central Numerics For Implicit Implementation
  - Other Coding Changes Are Minimal

- **Impact On Results**
  - Improves Robustness
  - Improves Node Stacking And Mixture Level Tracking Model

# Region Birthing Logic (12)

- **Difficulties Addressed**
  - Frequent Creation And Immediate Destruction Of Small Regions
  - Associated Degradation Of Robustness And Possibly Results

- **Description Of Model**
  - Allows Birth Of New Region Only If Deemed Viable
  - If Region Birthing Not Allowed, Appropriate Bookkeeping Done

- **Coding Impact**
  - Localized Coding Changes (BEFORE)
  - Logic-Intensive Coding

- **Impact On Results**
  - Improves Robustness
  - Permits Point Contact Links At Tops And Bottoms Of Nodes
  - Improves Node Stacking And Mixture Level Tracking Model

# Mixture Level Overshoot (7)

- **Difficulties Addressed**
  - Non-Physical Behavior Of Stacking Model During Overshoot

- **Description Of Modifications**
  - Depletion Logic Changes During Draining And Filling (FLOWLIM)
  - Level Crossing Logic In Stack For Mass-Based Flow Links (FLOW)

- **Coding Impact**
  - Localized Coding Changes (FLOW And FLOWLIM)

- **Impact On Results**
  - Improves Robustness
  - Improves Node Stacking And Mixture Level Tracking Model

# Internally Calculated Liquid Reflux Flow Links (6)

AP600

- **Difficulties Addressed**
  - Non-Physical Depressurization From Subcooled Liquid Into Vapor Region

- **Description Of Model**
  - Cascades Liquid Down To Highest Mixture Region In Stack
  - Generalization Of Vessel Liquid Reflux Flow Links

- **Coding Impact**
  - Special Flow Link Type (ITYPEFL = 4)
  - Easily Integrated Into Central Numerics

- **Impact On Results**
  - SG Tubes
  - Downcomer (For SPES-2)
  - CMT's
  - Balance Lines

# Condensation (13)

- **Difficulties Addressed**
  - Discontinuity Between Saturated And Subcooled Heat Transfer

- **Description Of Modifications**
  - Internally Calculated Film Heat Transfer Coefficient
    - Maximum of Shah And Nusselt
      - Continuous
      - Appropriate Limits
  - User-Input Constant Film Heat Transfer Coefficient

- **Coding Impact**
  - Minimal Coding

- **Impact On Results**
  - Provides Continuity For Increased Robustness
  - Allows For User-Supplied Constant Coefficients

# Critical Heat Flux (13)

- **Difficulties Addressed**
  - Macbeth Correlation Not Applicable To Stagnant Conditions
- **Description Of Modifications**
  - Zuber Critical Heat Flux Correlation As Lower Limit
- **Coding Impact**
  - Minimal Localized Changes (HEAT)
- **Impact On Results**
  - Treats Stagnant Conditions

# Implementation Of Transition Boiling Correlation (20)

- **Difficulties Addressed**
  - Non-Convergence Problems With Successive Substitution Iterative Scheme

- **Description Of Modifications**
  - Replace With Half-Interval Method
    - Guarantees Convergence
  - Make CHF The Upper Limit On Heat Flux
    - Ensures A Reasonable Result

- **Coding Impact**
  - Localized Coding Changes (HEAT)

- **Impact On Results**
  - Improves Robustness
  - Changes Are Not Optional

# Henry-Fauske / HEM Critical Flow Correlation

AP600

- **Difficulties Addressed**
  - Wanted These Correlations For ADS Flows
  - Also For SPES-2 And OSU Break Flows

- **Description Of Modifications**
  - Henry-Fauske For Subcooled
  - HEM For Saturated And Superheated

- **Coding Impact**
  - Model Taken Directly From RELAP4/MODE
  - Localized Changes (HFSATUR, HEMFLOW, and FLOW)

- **Impact On Results**
  - Meets Needs For These Correlations

# Summary Of NOTRUMP Model Improvements

AP600

- **18 Improvements in 5 Categories**
  - Address Specific Difficulties

- **Overall Minimal Coding Impact**

- **Overall Positive Impact On Results**
  - Improves Robustness
  - Allows Code To Run To And At Low Pressures
  - Allows Code To Run Without Intervention

# SUMMARY

Earl Novendstern
Manager, Advanced Plant Safety Analysis

# Assessment of Code Enhancements

- **Identify non-impact of the AP600 related model improvements**

  o Two operating plants were analyzed with the AP600 models invoked

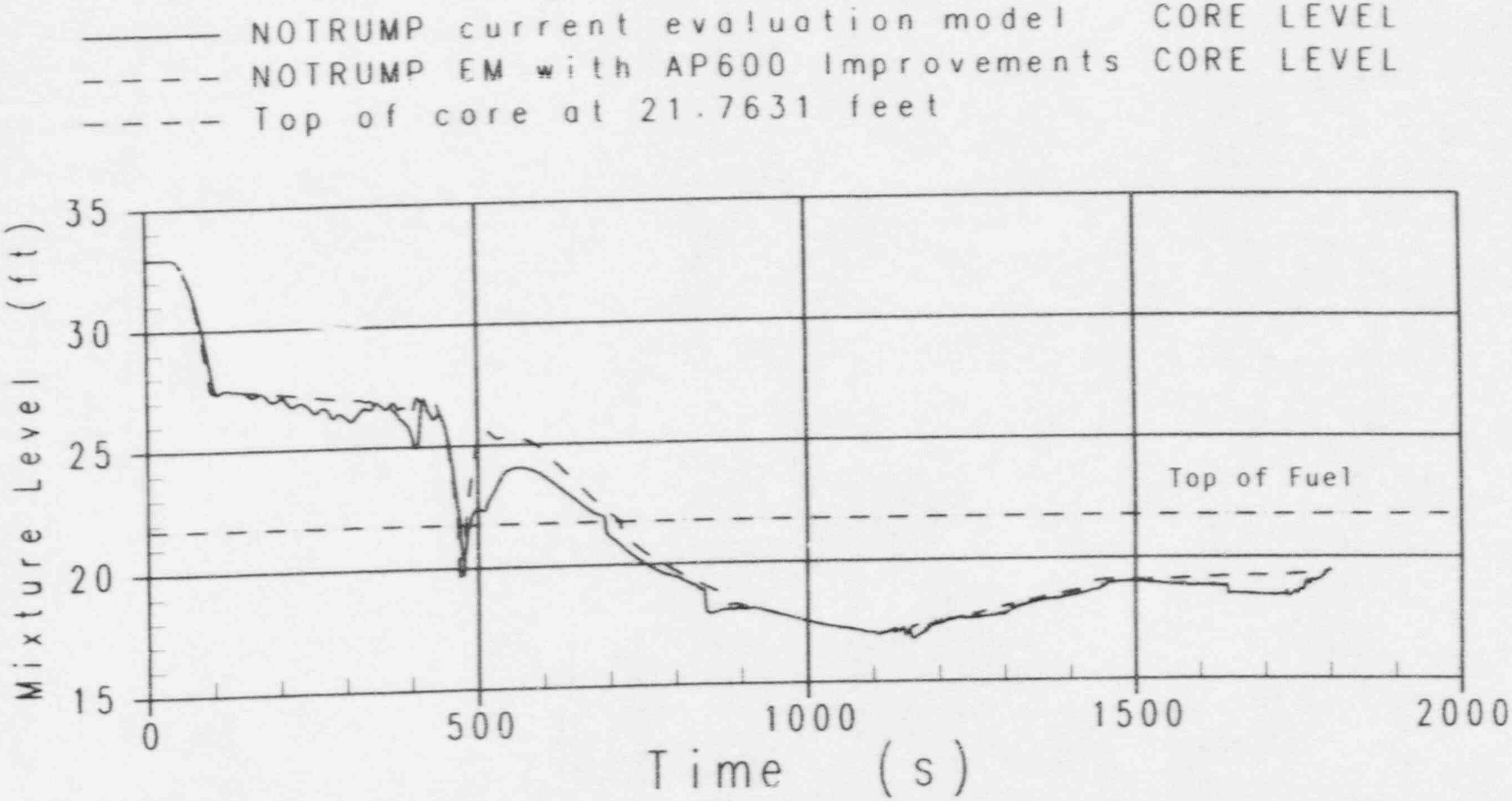
  o Results compared with current EM results for the limiting breaks

    - Transient behavior very similar with or without AP600 models
    - Impact on Calculated PCT less than 10°F
    - Code more "robust"

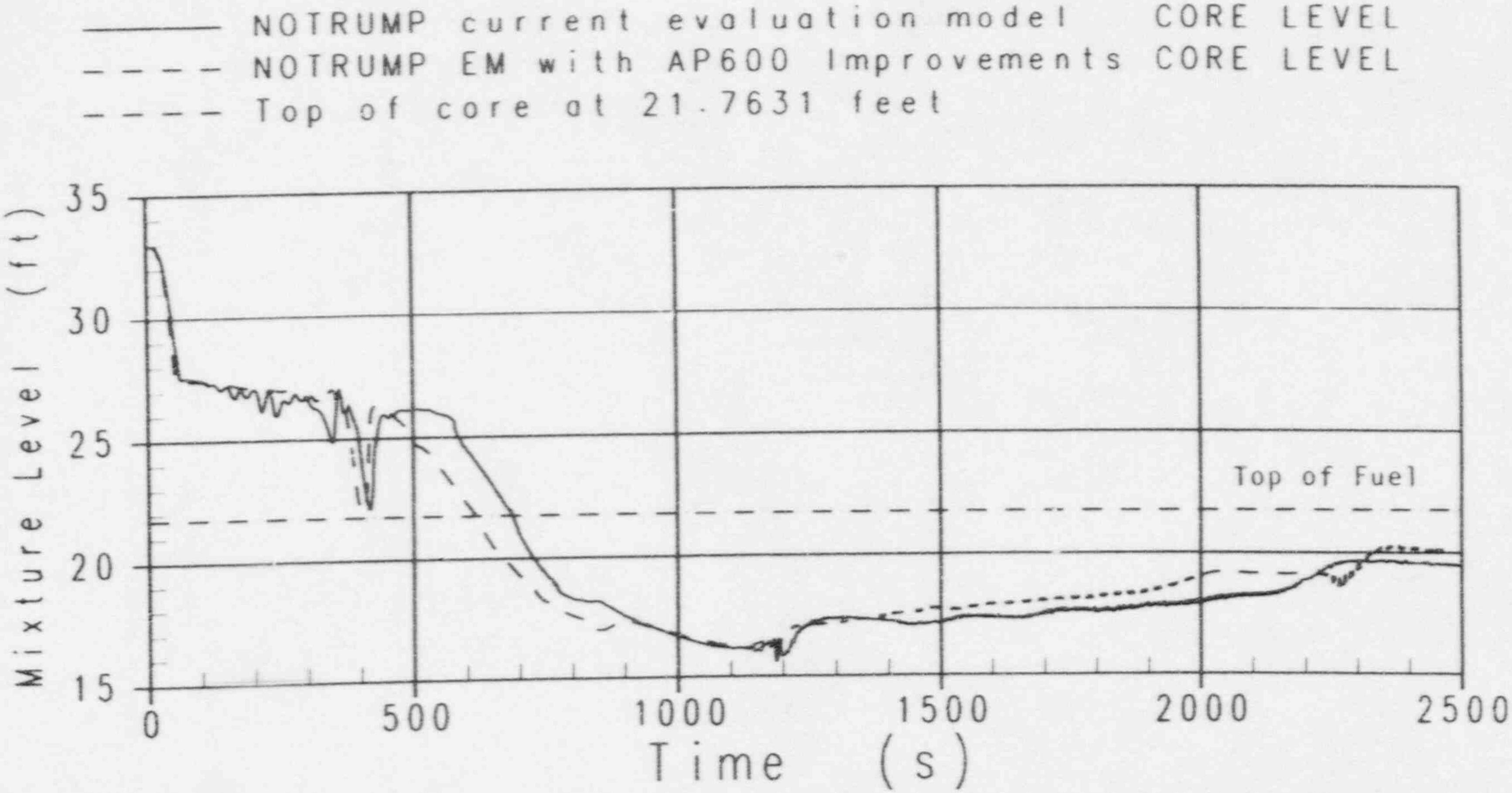
- **Results demonstrate that the AP600-related model improvements do not result in differences from the validated NOTRUMP**

# PRELIMINARY

## Plant A Comparison

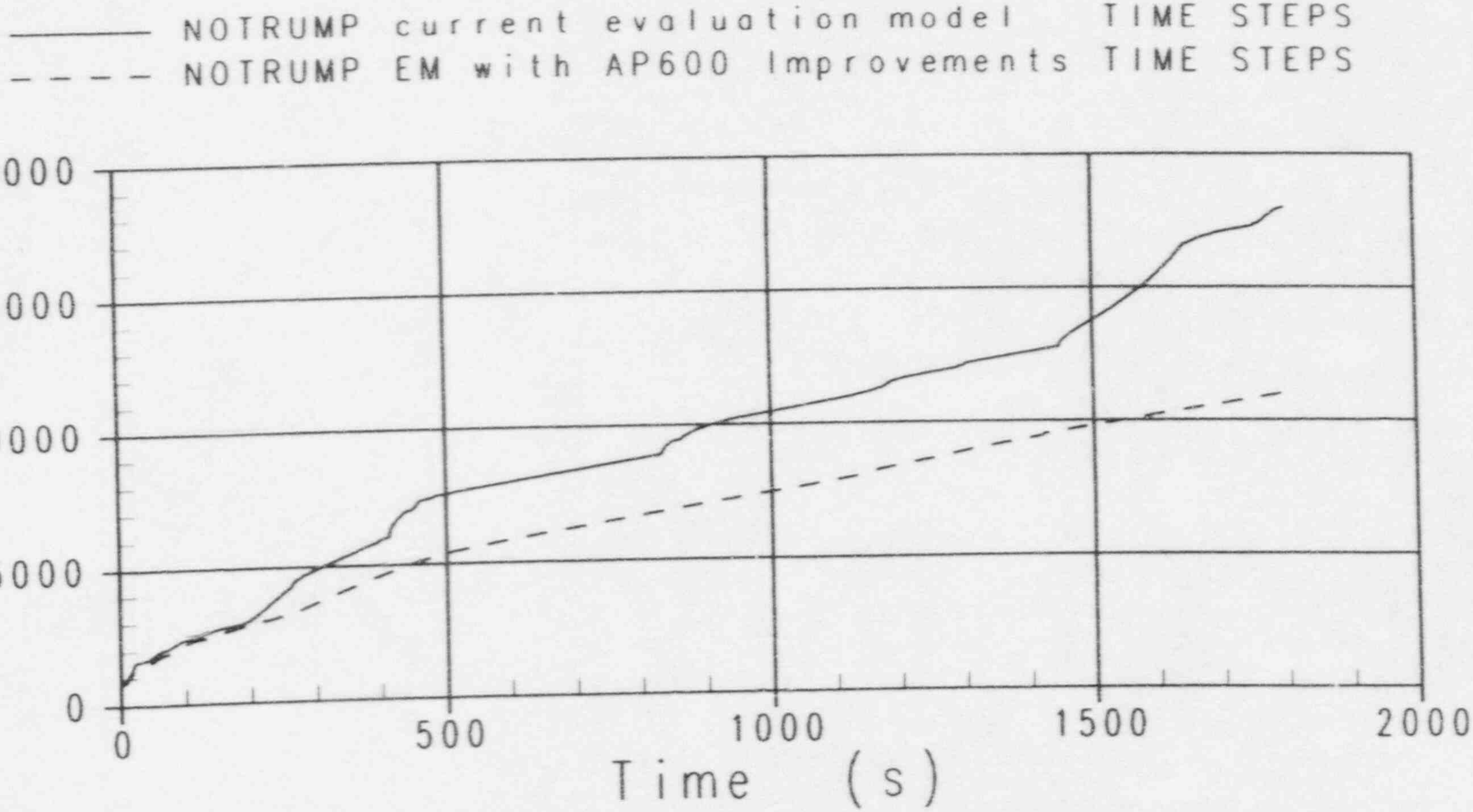


# PRELIMINARY
# Plant B Comparison



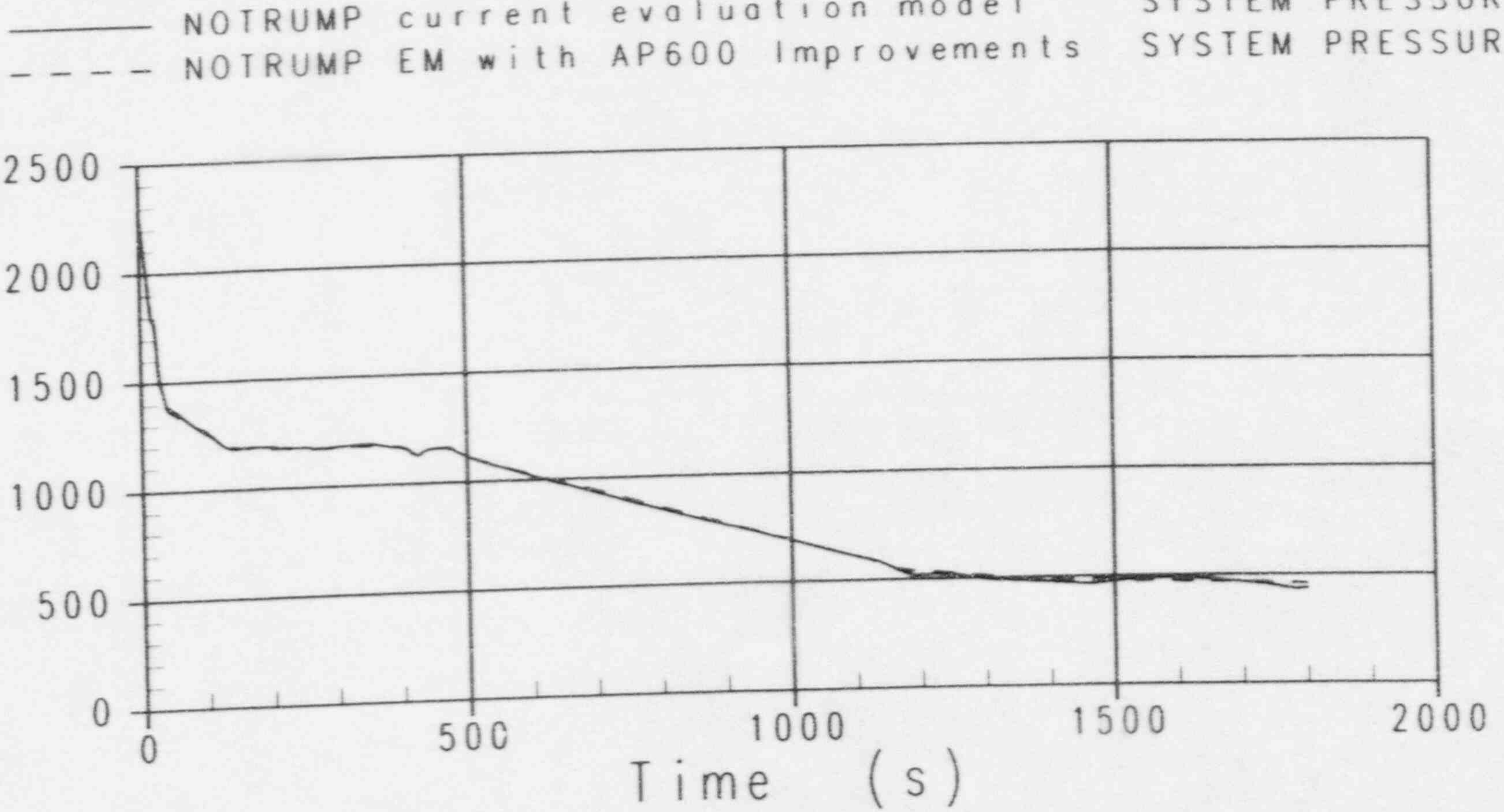
# PRELIMINARY

## Plant A Comparison



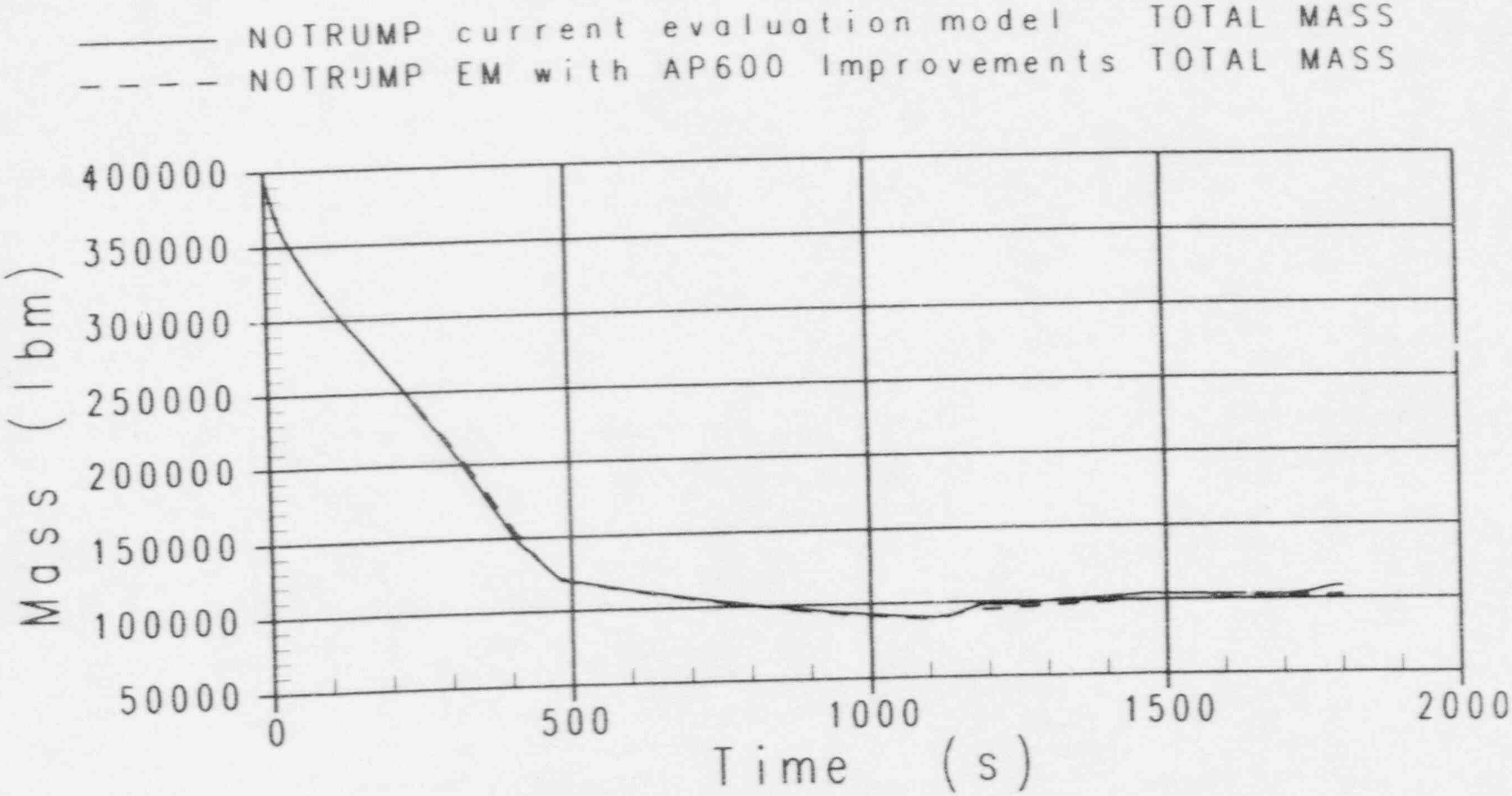
# PRELIMINARY

## Plant A Comparison



# PRELIMINARY

## Plant A Comparison



# Summary

NOTRUMP Modeling Changes Address AP600 Needs

- Five Categories Encompass 18 Questions
- Needed Primarily for Low Pressure and Passive Features
- Overall Minimum Coding Impact

Code With Changes to Model AP600 Attributes Yields Very Similar Results as Base NOTRUMP

W/NRC Communication on Model Changes Could Have Been Better

W/NRC Need to Determine how to "Go Forward" in an Efficient Manner that Supports AP600 SDSER and FSER Schedules