

SMAC 2003

The Automatic Iteration of SMAC

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SMAC2003

The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
- Research Approach
- Results
- Discussion and Conclusions
- Future Plans



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SMAC2003

The Automatic Iteration of SMAC

- What is SMAC?
 - Simulation Model of Automobile Collisions
 - Similar to performing a mathematical full-scale test
 - Created in response to need for more accurate reconstructions and uniform interpretation of evidence



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SMAC2003

The Automatic Iteration of SMAC

- What is SMAC?
 - SMAC Includes:
 - Trajectory Model
 - Tires forces modeled pre-impact, during impact, post impact
 - Conservation of Linear *and* Angular Momentum throughout the simulated event



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SMAC2003

The Automatic Iteration of SMAC

- What is SMAC?
 - SMAC Includes:
 - Collision Model
 - Finite duration of the impact
 - Tire forces fully active during collision



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SMAC2003

The Automatic Iteration of SMAC

- What is SMAC?
 - The inclusion of both Trajectory & Collision Models in SMAC reduces sensitivity to any limitations of either technique
 - SMAC Includes provisions for multiple impact, sustained contacts and provides generality



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SMAC2003 The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
 - Reduces or eliminates the need to manually iterate
 - Provides testing and refinement of evidence match.
 - Allows sensitivity testing of input variables
 - Includes unlimited objective iterations



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SMAC2003 The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
 - Saves time!
 - Time required for “best match” limited only by processor speed



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SMAC2003 The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
 - Jones, SAE 750894
 - “To make SMAC ‘user-orientated’ so that users can operate with ease”
 - Found that it is “insufficient to iterate on rest positions alone”



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SMAC2003 The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
 - Moffatt and Byrd, 1980 (DOT-HS-8-01820)
 - Iterated impact speeds, steering & braking
 - Limited by computer costs and capabilities



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SMAC2003 The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
 - CRASH-97 – 1997, (SAE 970949)
 - Used automatic iteration of SMAC for motions between separation and rest to refine separation speeds
 - Did not include collision simulation due to computational time considerations



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SMAC2003 The Automatic Iteration of SMAC

- What is SMAC?
- Why Automatically Iterate SMAC?
- Prior Work
- Research Approach
 - With advent of gigahertz Pentium machines, iteration of complete SMAC including collision feasible
 - This project an extension of our prior work on CRASH-97 (SAE 970949)



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Research Approach:

- Create a “function” which provides a measure of the correlation of a SMAC reconstruction with measured evidence
- Choose or create a function minimization routine to guide iterations of SMAC to minimize the “function”



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Correlation factor function

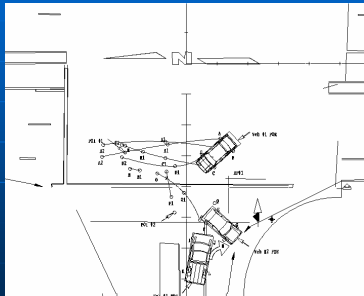
- What are important measures in any accident reconstruction?
 - Trajectory measurements
 - Damage measurements



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Trajectory Measurements Use Measured Scene Evidence



- Directions of travel
- Approx POI
- POR
- Tire tracks and characteristics
- Skidding? Tracking?



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SMAC Correlation Function

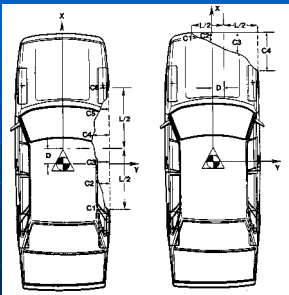
- Trajectory measurements
 - The approximate positions and orientations of the vehicles at impact
 - The measured positions and orientations of the vehicles at rest
 - Distance POI to POR for each vehicle
 - Azimuth angle POI to POR for each vehicle
 - Direction of the System Momentum



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Damage Measurements: Use Vehicle Damage Evidence



- Measure and Define Damage per:
- Collision Deformation Classification (SAE J224 MAR80)
 - Equidistant Crush Measurement (SAE J2433)
 - Tumbas & Smith (SAE 880072) Damage Measurement Protocol



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SMAC Correlation Function

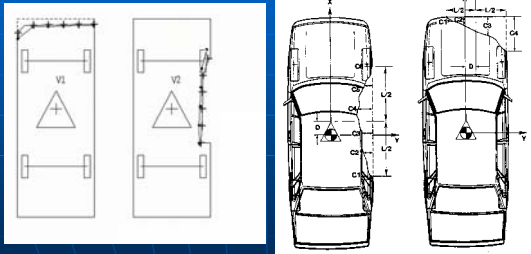
- Damage measurements:
 - Damage width
 - Damage depth
 - Damage area
 - Centroid of the damage region
 - Clock direction of the approximate PDOF



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SMAC Correlation Factor Damage



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ITERATION PROCEDURE

- Collision responses highly nonlinear
 - Any function minimization technique must handle step discontinuities
 - Restarts to insure a global v local minimum
- Weighting factors to establish priorities
 - Initially to grossly match evidence
 - Secondly to assist in refinement of match
- Auxiliary calculations and checks
 - To help guide the iteration procedure

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ITERATION PROCEDURE

- Starting Values for ITERATION
 - Original intent was simply for improvement
 - CRASH-type interface and information
 - CRASH original intent as SMAC preprocessor
 - Information required:
 - Impact positions and headings.
 - Rest positions and headings.
 - Wheel steer and drag
 - Vehicle type and specifications
 - Damage measurements.

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ITERATION PROCEDURE

- For Initial development and testing of SMACITER
 - Used SMAC generated reconstructions based on the RICSAC tests
- Final testing of SMACITER
 - Used 'raw' reported test results and other high confidence reconstructions to test convergence ability of SMACITER

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ITERATION PROCEDURE

- Variables iterated
 - Initial Speeds and Positions
 - Steering and Braking
 - Minor adjustments of steering and braking within ranges of uncertainty during iteration
 - Sideslip and Angular Velocity Options
 - Provide ability to address control losses preceding impact

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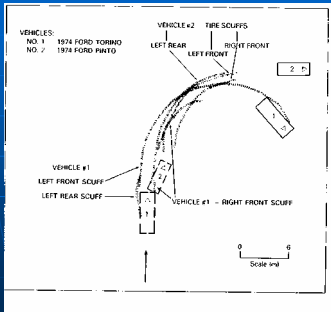
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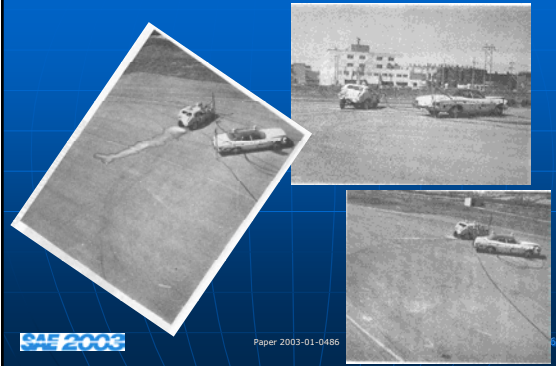
RICSAC Test#4



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RICSAC Test#4

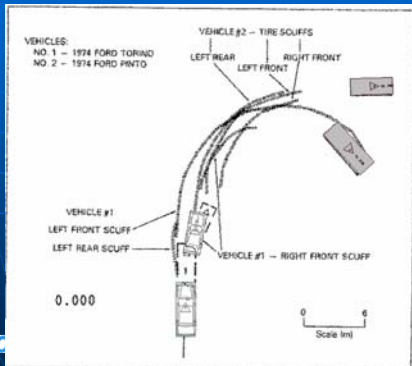


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RICSAC Test#4

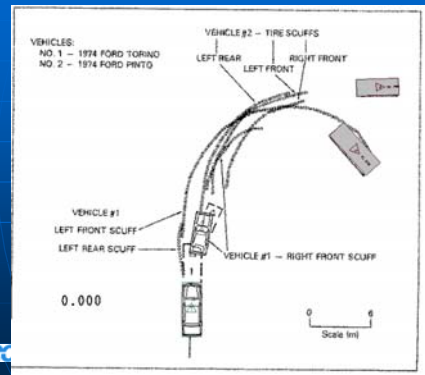
1st Pass with CRASH results: 31.9 MPH



Click on Picture for Animation

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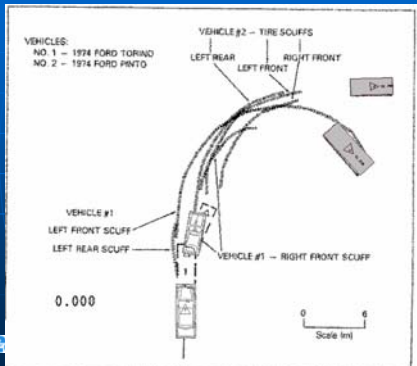
RICSAC Test#4 SMACITER



Click on Picture for Animation

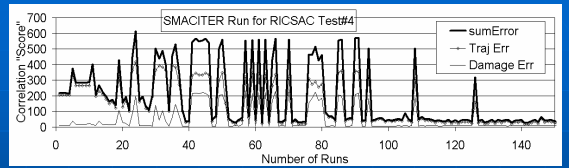
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RICSAC Test#4 SMACITER Final Results, 38.3 MPH

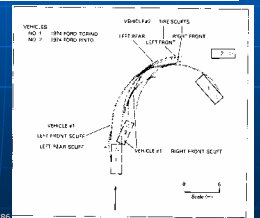


Click on Picture for Animation

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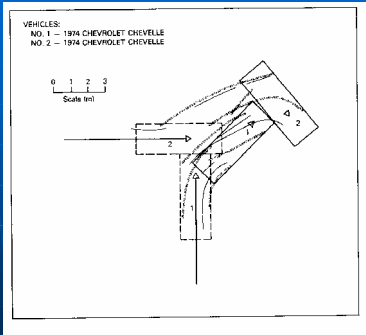
Correlation "Score" is a summation of the deviations from a perfect evidence match



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SAE 2003

RICSAC Test#8

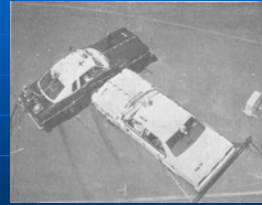


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RICSAC Test#8

Impact Speeds 20.8 MPH, 20.8 MPH

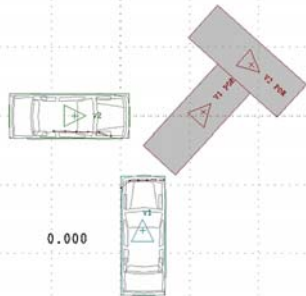


SAE 2003

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RICSAC Test#8, SMAC RUN with CRASH

Speeds 19.5 MPH, 24.5 MPH



Click on Picture for Animation

SAE

Graphic Display of Outputs of Accident Reconstruction
 SMAC Collision & Trajectory

VEHICLE DAMAGE AND INJURY											
VEHICLE DAMAGE		VEHICLE INJURY		VEHICLE DAMAGE		VEHICLE INJURY		VEHICLE DAMAGE		VEHICLE INJURY	
NO.	TYPE	NO.	TYPE	NO.	TYPE	NO.	TYPE	NO.	TYPE	NO.	TYPE
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2

Graphic Display of Outputs of Accident Reconstruction
 SMAC Collision & Trajectory

100 20 30 40 50 60 70 80 90 100

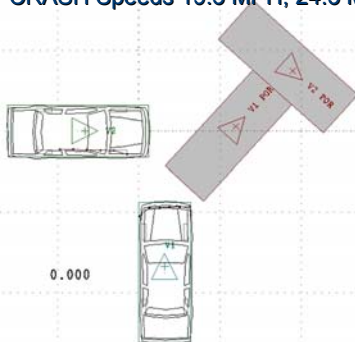
Results with CRASH speeds

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RICSAC Test#8, SMACITER Start with CRASH

Speeds 19.5 MPH, 24.5 MPH



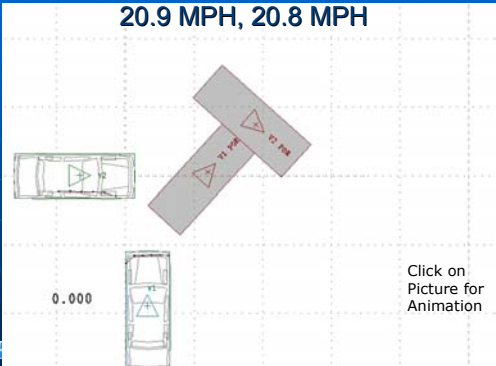
Click on Picture for Animation

SAE

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RICSAC Test#8, SMACITER RESULTS

20.9 MPH, 20.8 MPH

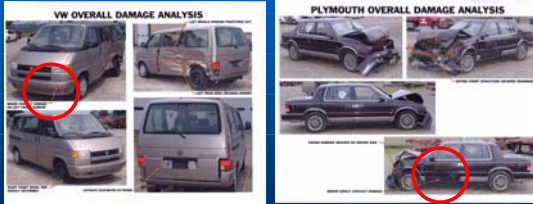


Click on Picture for Animation

SAE

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SMACITER Test with High Confidence Reconstruction



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SMACITER



Click on
Picture for
Animation



-6.912

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Final Result

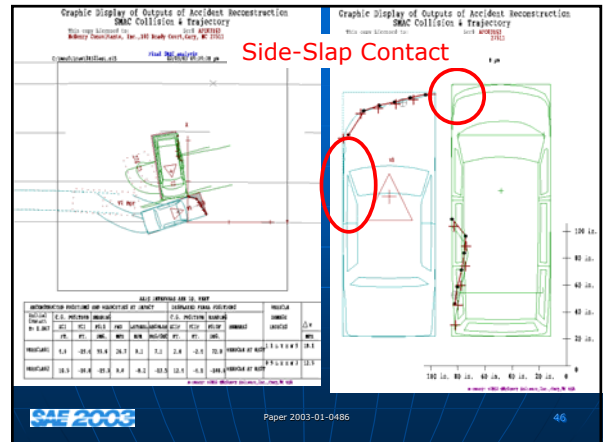


Click on
Picture for
Animation



-6.912

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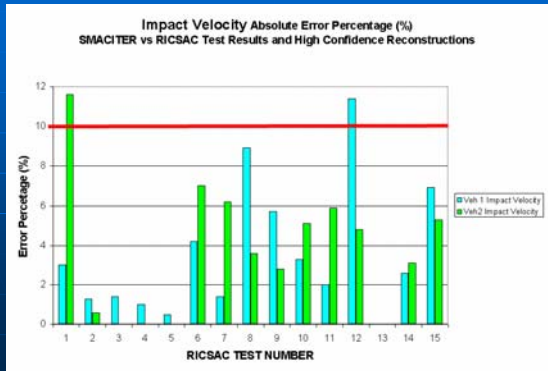
Discussion and Conclusions



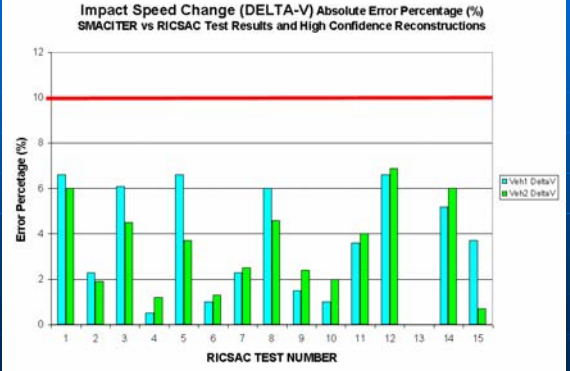
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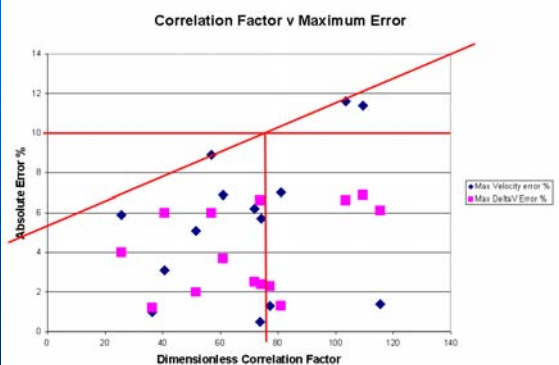
Impact Speed Correlation



ΔV Correlation



Correlation Factor v Error



Discussion and Conclusions

- SMACITER is a tool to aid and assist an accident investigation
- Feasibility of the automatic iteration of SMAC has been demonstrated
 - This research represents the 1st validation of SMAC without using Impact Speed as input
- SMACITER converges towards evidence match
 - Yields impact velocities within $\pm 12\%$
 - Yields ΔV 's within $\pm 8\%$



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Discussion and Conclusions

- CRASH serves its original purpose as a pre-processor for SMAC
- A correlation factor or "score" is a desirable means of ranking the achieved match of evidence and thereby the quality and reliability of the reconstruction



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FUTURE PLANS

- Additional refinements of SMACITER
- Complete comparison of SMACITER with all available full-scale tests
- Further evaluation of a correlation factor or “score” as a potential measure of reconstruction accuracy
- Implementation of Restitution enhancements per SAE 970960
- 3D components – merging of 2 HVOSM vehicles with refined SMAC



End of Presentation
Thank you!

