

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

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In the beginning....

Five modules in **REC-TEC** offer an alternative to requiring **V3** and **V4** speeds to reach a collision solution.

Digital Momentum, **Linear Momentum**, **PDOF/360LM** in the **360 LM** mode, **CrushV** Damage Analysis, and **Vectors (EDR - Momentum)** now can use the Longitudinal and Lateral DeltaV (or PDOF) of one vehicle to solve for DV1, DV2, V1, V2, V3, and V4. This method uses the Law of Sines, the Law of Cosines and Newton's Third Law of Motion. In Digital and Linear Momentum, and 360 LM the program solves for V3 and V4 using this method and uses those values to solve the Conservation of Linear Momentum (COLM) equations. In **Vectors (EDR-Momentum)** and **CrushV** it uses this method to solve for all of the unknowns.

Longitudinal DeltaV (X) - (CDR download)

Lateral DeltaV (Y) - (CDR download)

or

PDOF1 (Degrees) - User supplied

Angle 2 (Degrees)

Angle 3 (Degrees)

Angle 4 (Degrees)

**Slip Angle (Degrees) [Optional] – Angle between the Longitudinal Axis
of Vehicle 1 and its Post-Impact direction of travel**

Weight (1)

Weight (2)

With Event Data Recorder (EDR) downloads becoming increasingly available, this new methodology offers a valuable alternative to the V3 and V4 requirement, one not always as reliable or accurate as desired. It also offers a convenient cross check when V3 and V4 are available.

Formulae:

$$DV1 = DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle}))$$

$$DV2 = DV1 * (W1 / W2)$$

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$$\text{AngleC} = 180 - (\text{A3} + \text{PDOF1})$$

$$\text{AngleA} = \text{A2} - \text{A4}$$

$$\text{PDOF2} = 180 - (\text{PDOF1} + \text{A2})$$

$$\text{AngleB} = 180 - (\text{PDOF2} + \text{AngleA})$$

$$\text{V1} = \text{DV1} * \text{Sin}(\text{AngleC}) / \text{Sin}(\text{A3})$$

$$\text{V3} = \text{DV1} * \text{Sin}(\text{PDOF1}) / \text{Sin}(\text{A3})$$

$$\text{V2} = \text{DV2} * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$$

$$\text{V4} = \text{DV2} * \text{Sin}((180 - (\text{AngleB} + \text{AngleA})) / \text{Sin}(\text{AngleA}))$$

In **Digital Momentum**, **Linear Momentum** and **360 LM**, entering an “X” for V3 brings up a display for entering the Longitudinal DeltaV, PDOF and Slip Angle. The other variables should be entered in their regular locations for the particular module.

The **Vectors (EDR - Momentum)** module has entry locations for all of the required variables as long as no entry is made in the Lateral DeltaV input location. It also has a **Formulae*** button that will display the interactive formulae and variables used in the computations. The vector speed solutions are displayed in Primary and Secondary output modes along with a graphical display of the collision including DeltaV/PDOF vectors.

All of the Examples will use the following data except as noted:

Longitudinal DeltaV = 12.06 M/H

Angle 1 = 0 degrees

Angle 2 = 90 degrees

Angle 3 = 40 degrees

Angle 4 = 25 degrees

PDOF1 = 58 degrees

Slip Angle = 0 degrees

Weight 1 = 3000

Weight 2 = 2000

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Example 1 – Digital Momentum

Entering an “X” in the V3 Speed box brings up the DeltaV Computation Inputs frame.

Figure 1: Digital Momentum

The screenshot displays the REC-TEC Platinum software interface in DeltaV Mode. The main window shows a grid of input fields for vehicle parameters. A central 'DeltaV Computation Inputs' dialog box is open, allowing for the calculation of DeltaV based on user-defined inputs.

Parameter	Value
V1 (V1X)	10.0000
V1 (V1Y)	-40.0000
V1 Angle	0
V1 Weight	3000
PDOF (A1)	.0000
V3 (V3X)	30.0000
V3 (V3Y)	10.0000
V3 Angle	40
V3 Speed	0
V2 (V2X)	-30.0000
V2 (V2Y)	10.0000
V2 Angle	90
V2 Weight	2000
PDOF (A2)	-180.0000
V4 (V4X)	10.0000
V4 (V4Y)	50.0000
V4 Angle	25
V4 Speed	0

The 'DeltaV Computation Inputs' dialog box contains the following fields:

- DeltaV (X): 12.06
- PDOF1: 58 degrees
- Slip Angle: (empty)
- Execute button

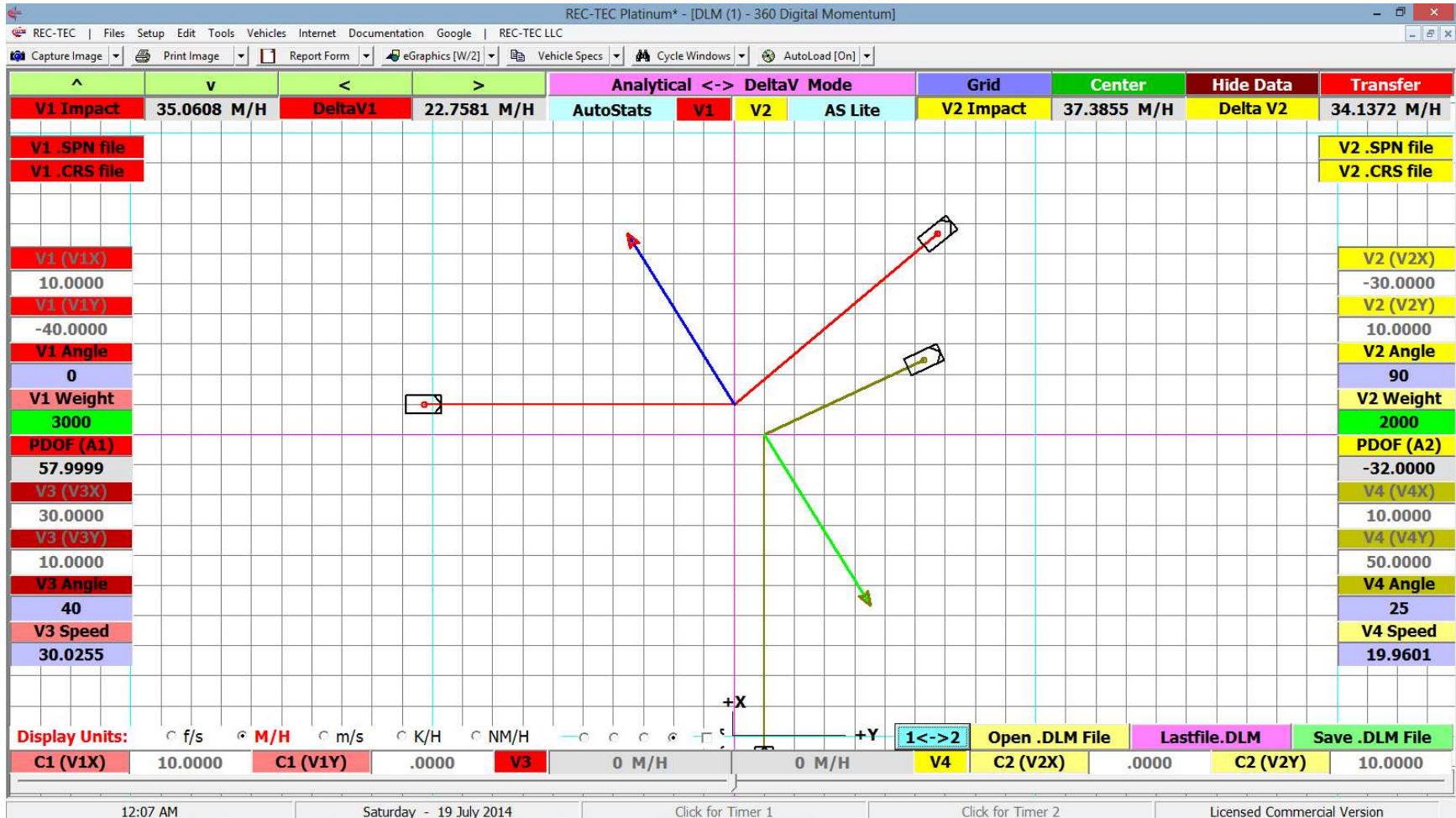
The status bar at the bottom shows the current date and time: Saturday - 19 July 2014, 12:06 AM. It also includes a timer and version information: Licensed Commercial Version.

Vectors (EDR-Momentum): Triangulating Momentum

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Entering the data and clicking on the **Execute** button creates Figure 2.

Figure 2: Digital Momentum



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Example 2 – 360 Linear Momentum

Entering an “X” in the V3 Speed brings up the DeltaV Computation Inputs frame and hides the V3 and V4 Speed inputs.

Figure 3: 360 Linear Momentum

Linear Momentum - Unit 1

Number of Fragments: 1 2 3 4

Inline Collision (EBS) LHCS/H

Inline Collision (V' & Ed or Dv1)

Approach Data:

Angle (1) degrees: 0

Departure Data: M/A File

Odd Fragments: 0

Angle (3) degrees: 40

Weight lbs: 3000

Unit 2

Number of Fragments: 1 2 3 4

V2 Speed (Known) M/H

Approach Data:

Angle (2) degrees: 90

Departure Data: M/A File

Even Fragments: 0

Angle (4) degrees: 25

Weight lbs: 2000

Enter X to Return to Speed Input

DeltaV Computation Inputs

DeltaV (X): 12.06

PDOF1 degrees: 58

Slip Angle degrees:

Execute

Navigation Menu:

- Energy Momentum
- Vector Analysis
- Velocity Vectors
- Iteration/FDA
- Formulae
- Graphics
- Animation
- Open .CSV File
- Formulae*
- 360LM > smac-RT
- Open .LMO File
- Save .LMO File

12:11 AM Saturday - 19 July 2014 Click for Timer 1 Click for Timer 2 Licensed Commercial Version

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Entering the data and clicking on the **Execute** button creates Figure 4.

Figure 4: 360 Linear Momentum

The screenshot shows the REC-TEC Platinum* software interface for calculating linear momentum. The window title is "REC-TEC Platinum* - [LMO (1) - 360 Linear Momentum]". The interface is divided into several sections:

- Linear Momentum - Unit 1:**
 - Number of Fragments: 1, 2, 3, 4 (radio buttons)
 - Collision Type: Inline Collision (EBS) (LHCS/H), Inline Collision (V' & Ed or Dv1)
 - Approach Data: Angle (1) = 0 degrees
 - Departure Data: M/A File
 - Odd Fragments: Angle (3) = 40 degrees, Weight = 3000 lbs, Speed (D) = 30.0255 M/H
 - Instructions: Enter 0 to use mu/Dist Input, Enter X to use DeltaV Inputs
- Unit 2:**
 - Number of Fragments: 1, 2, 3, 4 (radio buttons)
 - V2 Speed (Known): M/H
 - Approach Data: Angle (2) = 90 degrees
 - Departure Data: M/A File
 - Even Fragments: Angle (4) = 25 degrees, Weight = 2000 lbs, Speed (D) = 19.9601 M/H
 - Instructions: Enter 0 to use mu/Dist Input
- Output - Unit 1:**
 - PDOF (A1): 57.9999 degrees
 - Impulse: 3109.8119 lbf*s
 - DeltaV-Lat: 19.3 M/H, 28.3066 f/s
 - DeltaV-Lng: 12.0599 M/H, 17.6879 f/s
 - Delta V: 22.7581 M/H, 33.3786 f/s
 - Post Impact: Speed = 30.0255 M/H, 44.0374 f/s
 - Intercept (Pre-Impact): Angle = 90 degrees, Momentum = 129050.7236 M/H*lbs, Energy = 216552.3696 ft*lbf, 99597.289 ft*lbf, Speed = 51.2537 M/H, 75.172 f/s
 - Impact: Speed = 35.0608 M/H, 51.4225 f/s
 - eVelocity: .1314 - (e)
- Output - Unit 2:**
 - PDOF (A2): -32 degrees
 - Impulse: 3109.8119 lbf*s
 - DeltaV-Lat: -18.0899 M/H, -26.5319 f/s
 - DeltaV-Lng: 28.95 M/H, 42.46 f/s
 - Delta V: 34.1372 M/H, 50.0679 f/s
 - Post Impact: Speed = 19.9601 M/H, 29.2748 f/s
 - Separation (Post-Impact): Angle = 15 degrees, Momentum = 129050.7236 M/H*lbs, Energy = 116955.0805 ft*lbf, 105295.2376 ft*lbf, Speed = 11.9228 M/H, 17.4868 f/s
 - Impact: Speed = 37.3855 M/H, 54.8321 f/s
 - rVelocity: .2326 - (Vs/Vc)

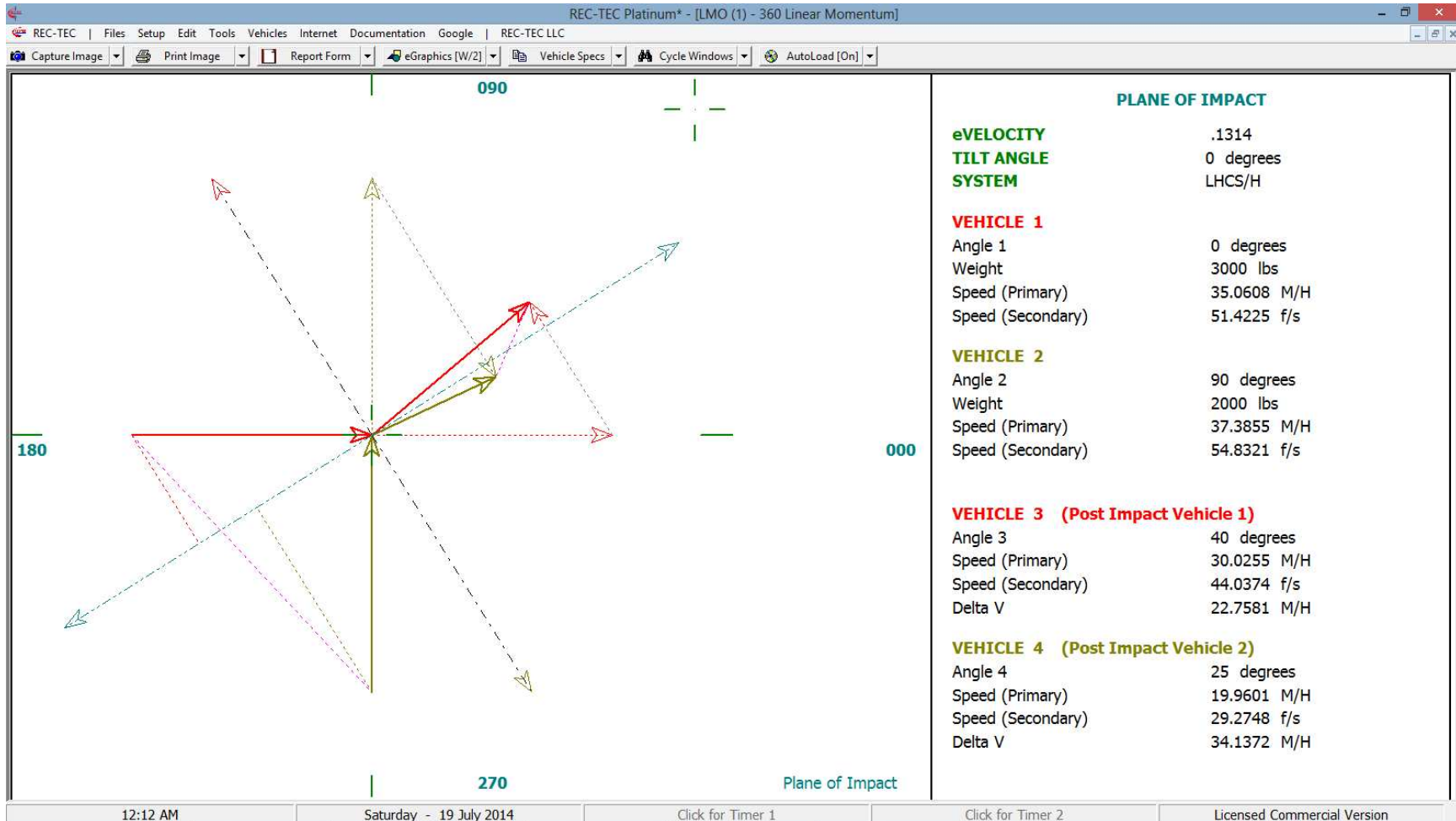
At the bottom, there is a navigation panel with buttons: Energy Momentum, Formulae, Formulae*, N, Vector Analysis, Graphics, 360LM > Vectors, Velocity Vectors, Animation, 360LM > smac-RT, Iteration/FDA, Open .CSV File, Open .LMO File, Save .LMO File.

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Figure 5 shows the Graphics – Right Clicking on the Graphics will bring up various Vector displays.

Figure 5: 360 Linear Momentum



Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Example 3 – 360 LM Lite

Entering an “X” in the V3 Speed box brings up the DeltaV Computation Inputs frame.

Figure 6: 360 LM Lite

The screenshot shows the REC-TEC Platinum software interface for the 360 LM Lite application. The window title is "REC-TEC Platinum* - [PDOF (1) - 360LM-PDOF Lite]". The interface is divided into several sections:

- Select Option:** Radio buttons for "PDOF" and "360 Momentum" (selected). A dropdown menu shows "LHCS/H".
- Required Inputs (Left):**
 - Angle A1: degrees 0
 - Angle A3: degrees 40
 - Weight V1: lbs 3000
 - Speed V3: M/H x
- Required Inputs (Right):**
 - Angle A2: degrees 90
 - Angle A4: degrees 25
 - Weight V2: lbs 2000
 - Speed V4: M/H See ToolTip
- DeltaV Computation Inputs (Center):** A green-bordered panel containing:
 - DeltaV (X): 12.06
 - PDOF1: degrees 58
 - Slip Angle: degrees (empty)
 - Execute button (pink)
- Output (Bottom Right):** A table of calculated values:

Angle 1	0	Speed 1		Weight 1	3000	PDOF A1	0
Angle 2	90	Speed 2		Weight 2	2000	PDOF A2	0
Angle 3	40	Speed 3		Angle(C)	90.0000	Speed(C)	0
Angle 4	25	Speed 4		Angle(S)	15.0000	Speed(S)	0
Delta V1	0	Delta V2	0	eVelocity	0 (e)	rVelocity	
- Formulas and File Management (Bottom Left):**
 - Formulae: N
 - Open .PFL File: 1<->2
 - Save .PFL File: -> LMO

The status bar at the bottom shows the time as 12:14 AM, the date as Saturday - 19 July 2014, and the version as Licensed Commercial Version.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Entering the data and clicking on the **Execute** button creates Figure 7.

Figure 7: 360 LM Lite

The screenshot shows the REC-TEC Platinum software interface for calculating momentum. The window title is "REC-TEC Platinum* - [PDOF (1) - 360LM-PDOF Lite]". The interface includes a menu bar, a toolbar, and several input sections.

Select Option: LHC/S/H, PDOF, **360 Momentum**

Required Inputs (Left):

- Angle A1: degrees 0
- Angle A3: degrees 40
- Weight V1: lbs 3000
- Speed V3: M/H 30.0255
- Angle A2: degrees 90
- Angle A4: degrees 25
- Weight V2: lbs 2000
- Speed V4: M/H 19.9601

Required Inputs (Right):

- Formulae: N
- Open .PFL File: 1<->2
- Save .PFL File: -> LMO

Diagram: A vector diagram showing two vehicles, Vehicle 1 (red line) and Vehicle 2 (yellow line), colliding. The resulting momentum vectors are shown as a green triangle and a blue triangle.

Output:

Angle 1	0	Speed 1	35.0608	Weight 1	3000	PDOF A1	57.9999
Angle 2	90	Speed 2	37.3855	Weight 2	2000	PDOF A2	-32
Angle 3	40	Speed 3	30.0255	Angle(C)	90.0000	Speed(C)	51.2537
Angle 4	25	Speed 4	19.9601	Angle(S)	15.0000	Speed(S)	11.9228
Delta V1	22.7581	Delta V2	34.1372	eVelocity	.1314 (e)	rVelocity	.2326 (Vs/Vc)

12:15 AM Saturday - 19 July 2014 Click for Timer 1 Click for Timer 2 Licensed Commercial Version

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Example 4 – Crush

Figure 8: Crush5 - Vehicle 1

The screenshot displays the REC-TEC Platinum software interface for a vehicle crush analysis. The main window is titled 'Crush5 - Vehicle 1' and shows various data fields and tables.

Crush5 - Vehicle 1 (Inches)

AutoStats data

Description	Car1	Optional Inputs	COLM Angles
Category	DFLT	PDOF	45
Weight (lb)	3000	Stiffness A	173.3
Damage Width	76	Stiffness B	57.1
Damage Offset		Stiffness G	262.985 lbf

Surface

Front Rear Right Left

Yaw Radius (Gyr)		Front Track	66
Wheelbase	108	Rear Track	66
CG - Front Axle	60	Tire Radius (F)	14
CG - Front	93	Tire Radius (R)	14
Vehicle Length	186	Tire Width (F)	7
Vehicle Width	73	Tire Width (R)	7

Crush5 Measurements (Inches)

Equidistant Measurements

C01	0	L01	0	100 %	C11		L11		%
C02	15	L02		100 %	C12		L12		%
C03	15	L03		100 %	C13		L13		%
C04	15	L04		100 %	C14		L14		%
C05	15	L05		100 %	C15		L15		%
C06	0	L06		%	C16		L16		%
C07		L07		%	C17		L17		%
C08		L08		%	C18		L18		%
C09		L09		%	C19		L19		%
C10		L10		%	C20		L20		%

Central Collision

Display Units: f/s M/H m/s K/H NM/H

Crush Energy	89342.2436 ft*lbf	91951.0591 ft*lbf
Equivalent Barrier Speed	29.8592 M/H	37.1 M/H
Mass (lb/in/sec^2)	7.7639	5.1759
Yaw Radius of Gyration	3327.0833 in^2	3324 in^2
Inertia Moment (Mass*RG)	25831.3923	17204.9689
CoD (X) - Depth	6.875 in (C)	7.5 in (C)
CoD (Y) - Width	38 in (C)	31.8 in (C)
Damage Area	912 in^2	954 in^2
Moment Arm (Length)	20.948 in	47.0226 in
Gamma (Y) Value	.8834	.6005
Linear Impulse	3050.7287 lbf*sec	
Collision Force (Peak)	92271.778 lbf	92271.7508 lbf
Energy - Dissipated	89342.2436 ft*lbf	91951.0591 ft*lbf
Energy - Dissipated (Total)	181293.3028 ft*lbf	
Energy - Maximum	263215.6479 ft*lbf	
Delta T	.0661 seconds	.0661 seconds
G (Acceleration Factor)	15.3786	23.0679
Speed - Closure	81.0357 M/H	
Speed - Equivalent Barrier	28.0657 M/H	28.7502 M/H
Delta V (Angular)	2.4739 rad/sec	8.3378 rad/sec
Delta V (Angular)	141.744 deg/sec	477.7207 deg/sec
Delta V (Longitudinal)	-15.7867 M/H	-23.68 M/H
Delta V (Lateral)	-15.7867 M/H	23.68 M/H
Delta V (Total)	22.3257 M/H	33.4886 M/H

Test Crash **C3 Manual** **Graphics Suite** **Formulae** **> 360 LM** **N**

Open .crs File **1** **2** **Save .crs File**

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 9: Crush5 - Vehicle 2

Crush5 - Vehicle (Inches)

AutoStats data | AutoStats Lite data

Description: Car2 | Optional Inputs: COLM Angles

Category: DFLT | PDOF: -45

Weight (lb): 2000 | Stiffness A: 115.9592

Damage Width: 63.6 | Stiffness B: 60.6614

Damage Offset: | Stiffness G: 110.8327 lbf

Surface: Front | Rear | Right | Left

Yaw Radius (Gyr): 3324 | Front Track: 50.4

Wheelbase: 96 | Rear Track: 50.4

CG - Front Axle: 37 | Tire Radius (F): 14

CG - Front: 74 | Tire Radius (R): 14

Vehicle Length: 156 | Tire Width (F): 7

Vehicle Width: 63.6 | Tire Width (R): 7

Crush5 Measurements (Inches) | Equidistant Measurements

C01	15	L01	0	100	%	C11	L11		%
C02	15	L02			%	C12	L12		%
C03		L03			%	C13	L13		%
C04		L04			%	C14	L14		%
C05		L05			%	C15	L15		%
C06		L06			%	C16	L16		%
C07		L07			%	C17	L17		%
C08		L08			%	C18	L18		%
C09		L09			%	C19	L19		%
C10		L10			%	C20	L20		%

Central Collision | Display Units: f/s | M/H | m/s | K/H | NM/H

Crush Energy: 89342.2436 ft*lb | 91951.0591 ft*lb

Equivalent Barrier Speed: 29.8592 M/H | 37.1 M/H

Mass (lb/in/sec^2): 7.7639 | 5.1759

Yaw Radius of Gyration: 3327.0833 in^2 | 3324 in^2

Inertia Moment (Mass*RG): 25831.3923 | 17204.9689

CoD (X) - Depth: 6.875 in (C) | 7.5 in (C)

CoD (Y) - Width: 38 in (C) | 31.8 in (C)

Damage Area: 912 in^2 | 954 in^2

Moment Arm (Length): 20.948 in | 47.0226 in

Gamma (Y) Value: .8834 | .6005

Linear Impulse: 3050.7287 lbf*sec

Collision Force (Peak): 92271.778 lbf | 92271.7508 lbf

Energy - Dissipated: 89342.2436 ft*lb | 91951.0591 ft*lb

Energy - Dissipated (Total): 181293.3028 ft*lb

Energy - Maximum: 263215.6479 ft*lb

Delta T: .0661 seconds | .0661 seconds

G (Acceleration Factor): 15.3786 | 23.0679

Speed - Closure: 81.0357 M/H

Speed - Equivalent Barrier: 28.0657 M/H | 28.7502 M/H

Delta V (Angular): 2.4739 rad/sec | 8.3378 rad/sec

Delta V (Angular): 141.744 deg/sec | 477.7207 deg/sec

Delta V (Longitudinal): -15.7867 M/H | -23.68 M/H

Delta V (Lateral): -15.7867 M/H | 23.68 M/H

Delta V (Total): 22.3257 M/H | 33.4886 M/H

Test Crash | C3 Manual | Graphics Suite | Formulae | > 360 LM | N

Open .crs File | 1 | 2 | Save .crs File

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Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Click on COLM button to add angles

Figure 10: Crush5 - COLM Angles

The screenshot displays the REC-TEC Platinum software interface for a vehicle crash analysis. The main window is titled 'Crush5 - Vehicle (Inches)' and shows various data fields and calculation results.

Crush5 - Vehicle (Inches) - LastFile1.crs

AutoStats data

Description	Car1	Optional Inputs	COLM Angles
Category	DFLT	PDOF	45
Weight (lb)	3000	Stiffness A	173.3
Damage Width	76	Stiffness B	57.1
Damage Offset		Stiffness G	262.985 lbf
Surface	Front	Stiffness A	173.3
Yaw Radius (Gyr)		Stiffness B	57.1
Wheelbase	108	Stiffness G	262.985 lbf
CG - Front Axle	60	Front Track	66
CG - Front	93	Rear Track	66
Vehicle Length	186	Tire Radius (F)	14
Vehicle Width	73	Tire Radius (R)	14
		Tire Width (F)	7
		Tire Width (R)	7

Crush5 Measurements (Inches)

Crush5 Measurements (Inches)				Equidistant Measurements							
C01	0	L01	0	100	%	C11		L11			%
C02	15	L02		100	%	C12		L12			%
C03	15	L03		100	%	C13		L13			%
C04	15	L04		100	%	C14		L14			%
C05	15	L05		100	%	C15		L15			%
C06	0	L06			%	C16		L16			%
C07		L07			%	C17		L17			%
C08		L08			%	C18		L18			%
C09		L09			%	C19		L19			%
C10		L10			%	C20		L20			%

Central Collision - Display Units: M/H

Crush Energy: 89342.2436 ft*lbf / 91951.0591 ft*lbf
 Equivalent Barrier Speed: 29.8592 M/H / 37.1 M/H

COLM Angles - LHCS/H - A1 = 0

Angle 2	degrees	90	5.1759
Angle 3	degrees	60	3324 in^2
Angle 4	degrees	30	17204.9689
			7.5 in (C)
			31.8 in (C)
			954 in^2
			47.0226 in
			.6005

Linear Impulse: 3050.7287 lbf*sec

Collision Force (Peak) 92271.778 lbf / 92271.7508 lbf

Energy - Dissipated: 89342.2436 ft*lbf / 91951.0591 ft*lbf

Energy - Dissipated (Total): 181293.3028 ft*lbf

Energy - Maximum: 263215.6479 ft*lbf

Delta T: .0661 seconds / .0661 seconds

G (Acceleration Factor): 15.3786 / 23.0679

Speed - Closure: 81.0357 M/H

Speed - Equivalent Barrier: 28.0657 M/H / 28.7502 M/H

Delta V (Angular): 2.4739 rad/sec / 8.3378 rad/sec

Delta V (Angular): 141.744 deg/sec / 477.7207 deg/sec

Delta V (Longitudinal): -15.7867 M/H / -23.68 M/H

Delta V (Lateral): -15.7867 M/H / 23.68 M/H

Delta V (Total): 22.3257 M/H / 33.4886 M/H

V1 Speed | V2 Speed 24.9011 M/H / 37.3517 M/H

V3 Speed | V4 Speed 18.2289 M/H / 27.3433 M/H

Buttons: Test Crash, C3 Manual, Graphics Suite, Formulae, > 360 LM, Save .crs File, Open .crs File, COLM

System Info: 12:27 AM, Saturday - 19 July 2014, Click for Timer 1, Click for Timer 2, Licensed Commercial Version

Vectors (EDR-Momentum): Triangulating Momentum

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Figure 11: Crush5 - Pre Impact & Post Impact Speeds

The screenshot displays the REC-TEC Platinum software interface for a crash test analysis. The window title is "REC-TEC Platinum* - [CRS (1) - Crush5 LastFile1.crs LastFile2.crs]". The interface is divided into several sections:

- Crush5 - Vehicle (Inches):** Contains vehicle specifications for "Car1".

Description	Car1	Optional Inputs	COLM Angles
Category	DFLT	PDOF	45
Weight (lb)	3000	Stiffness A	173.3
Damage Width	76	Stiffness B	57.1
Damage Offset		Stiffness G	262.985 lbf
Surface	<input type="radio"/> Front <input type="radio"/> Rear <input checked="" type="radio"/> Right <input type="radio"/> Left		
Yaw Radius (Gyr)		Front Track	66
Wheelbase	108	Rear Track	66
CG - Front Axle	60	Tire Radius (F)	14
CG - Front	93	Tire Radius (R)	14
Vehicle Length	186	Tire Width (F)	7
Vehicle Width	73	Tire Width (R)	7
- Crush5 Measurements (Inches):** A table showing measurements for 20 points (C01-C20) and 10 locations (L01-L10).

Point	Value	Unit	Point	Value	Unit
C01	0	%	C11		%
C02	15	%	C12		%
C03	15	%	C13		%
C04	15	%	C14		%
C05	15	%	C15		%
C06	0	%	C16		%
C07		%	C17		%
C08		%	C18		%
C09		%	C19		%
C10		%	C20		%
- Central Collision:** Displays collision statistics.

Crush Energy	89342.2436 ft*lbf	91951.0591 ft*lbf
Equivalent Barrier Speed	29.8592 M/H	37.1 M/H
Mass (lb/in/sec^2)	7.7639	5.1759
Yaw Radius of Gyration	3327.0833 in^2	3324 in^2
Inertia Moment (Mass*RG)	25831.3923	17204.9689
CoD (X) - Depth	6.875 in (C)	7.5 in (C)
CoD (Y) - Width	38 in (C)	31.8 in (C)
Damage Area	912 in^2	954 in^2
Moment Arm (Length)	20.948 in	47.0226 in
Gamma (Y) Value	.8834	.6005
Linear Impulse	3050.7287 lbf*sec	
Collision Force (Peak)	92271.778 lbf	92271.7508 lbf
Energy - Dissipated	89342.2436 ft*lbf	91951.0591 ft*lbf
Energy - Dissipated (Total)	181293.3028 ft*lbf	
Energy - Maximum	263215.6479 ft*lbf	
Delta T	.0661 seconds	.0661 seconds
G (Acceleration Factor)	15.3786	23.0679
Speed - Closure	81.0357 M/H	
Speed - Equivalent Barrier	28.0657 M/H	28.7502 M/H
Delta V (Angular)	2.4739 rad/sec	8.3378 rad/sec
Delta V (Angular)	141.744 deg/sec	477.7207 deg/sec
Delta V (Longitudinal)	-15.7867 M/H	-23.68 M/H
Delta V (Lateral)	-15.7867 M/H	23.68 M/H
Delta V (Total)	22.3257 M/H	33.4886 M/H
V1 Speed V2 Speed	24.9011 M/H	37.3517 M/H
V3 Speed V4 Speed	18.2289 M/H	27.3433 M/H
- Buttons:** "Test Crash", "C3 Manual", "Graphics Suite", "Formulae", "> 360 LM", "Open .crs File", "Save .crs File", and "N".

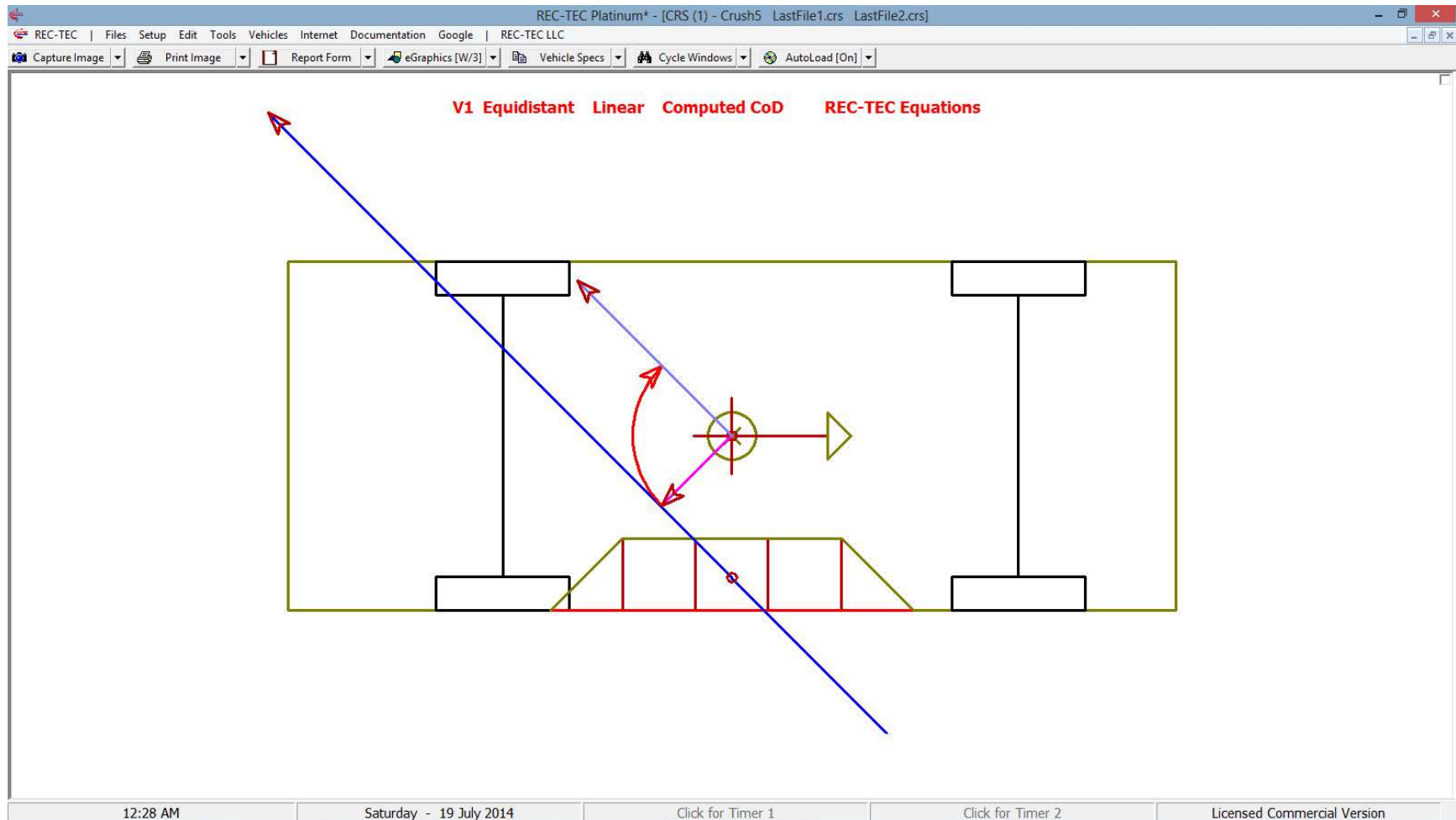
The status bar at the bottom shows the time as 12:27 AM on Saturday, 19 July 2014, and indicates it is a Licensed Commercial Version.

Clicking on **Graphics Suite** button brings up Vehicle 1 Graphics

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 12: Crush5 - Vehicle 1 Graphics

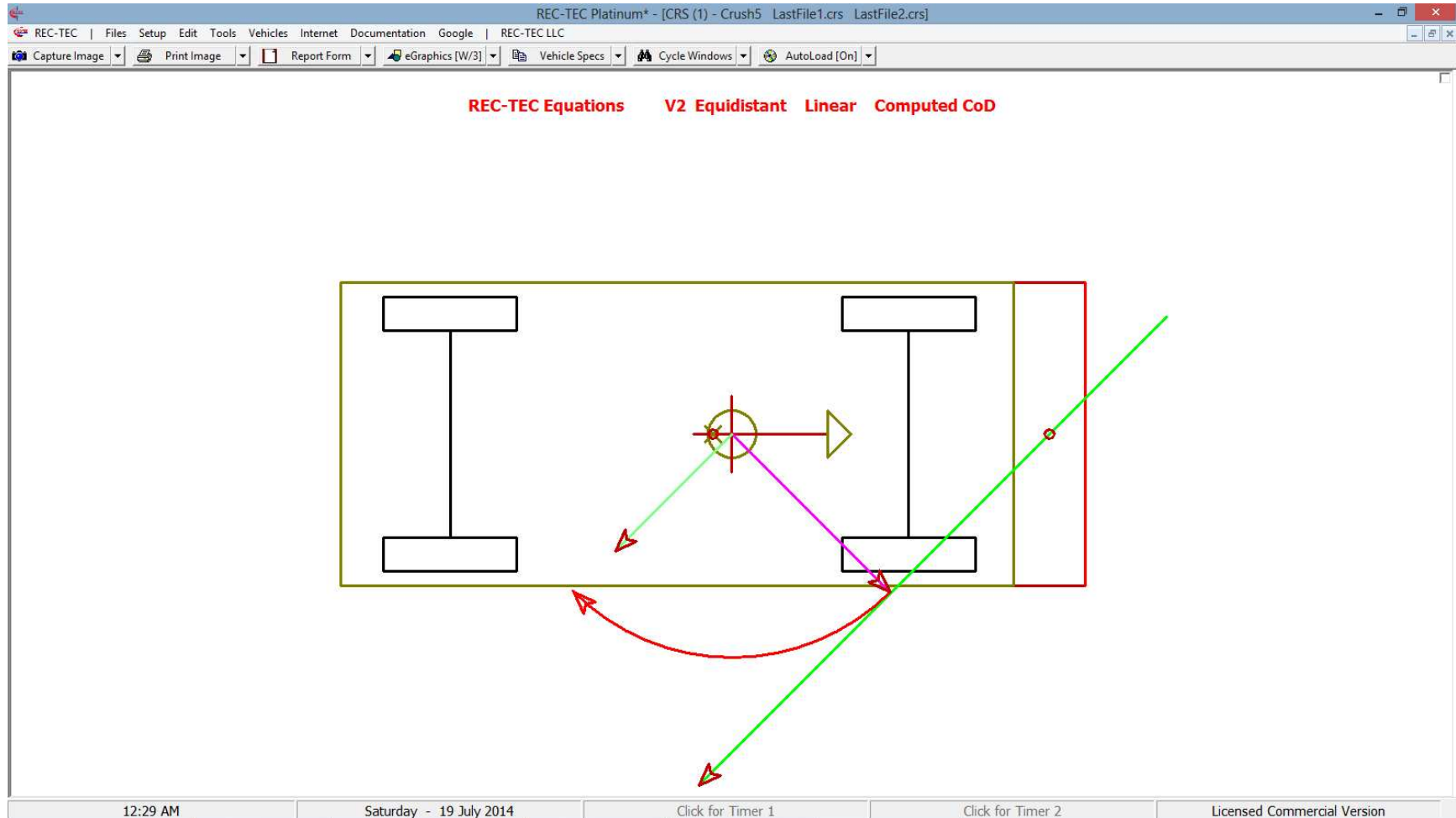


Use the **Escape [Esc]** key to advance to next Screen or **Right** click on Graphics to Re-draw the graphics.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

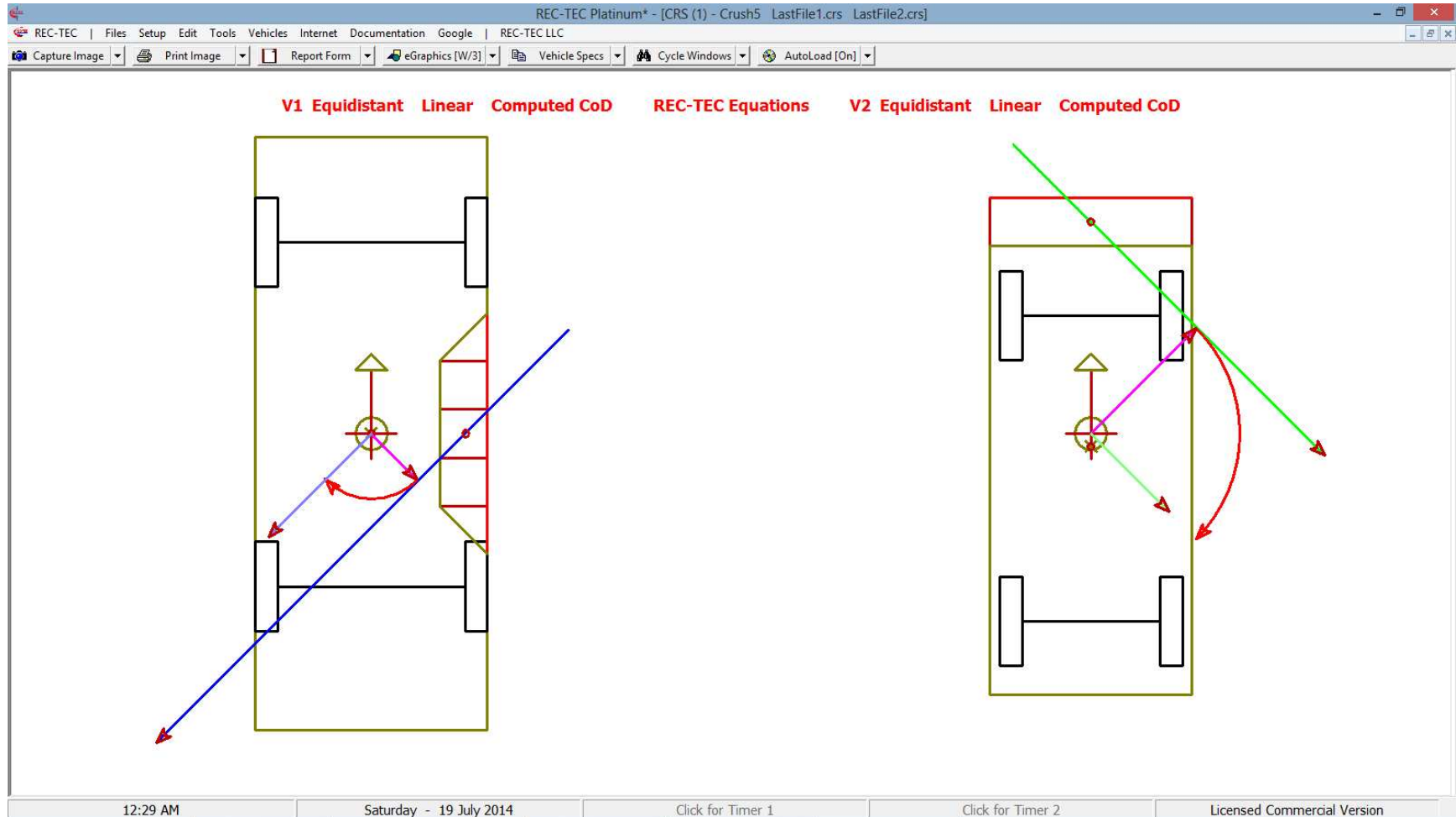
Figure 13: Crush5 - Vehicle 2 Graphics



Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

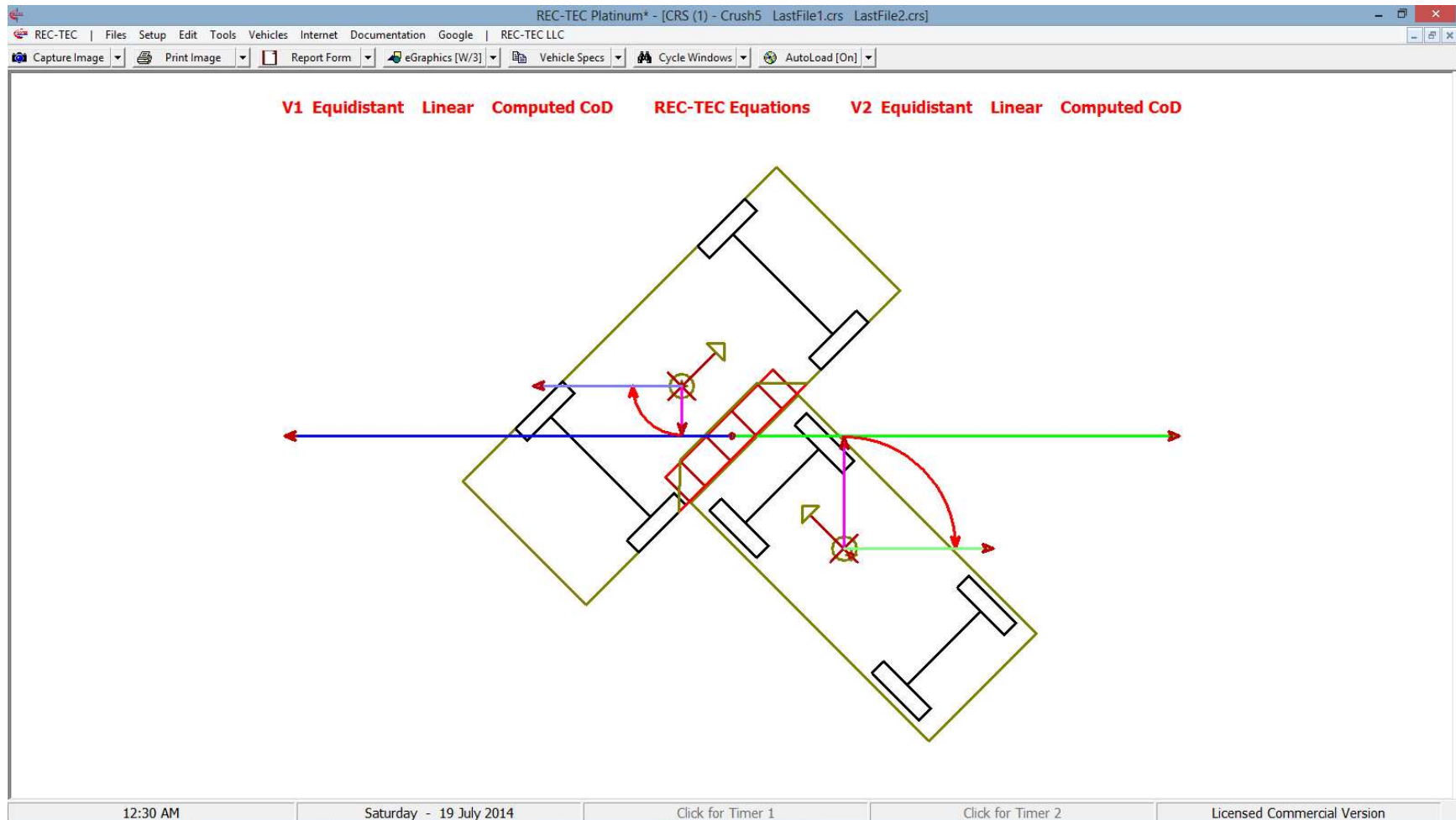
Figure 14: Crush5 - Vehicles 1 & 2 (Side-by-Side)



Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 15: Crush5 - Vehicles 1 & 2 (Maximum Engagement)



Vectors (EDR-Momentum): Triangulating Momentum

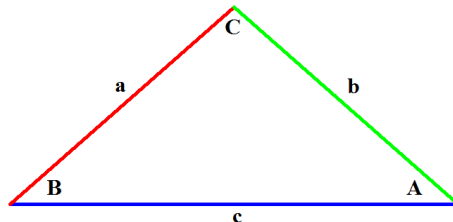
Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Triangulation:

Before diving into **Vectors (EDR-Momentum)** a little history on how and why this works is in order. We will be working with Triangles. There are a lot of AI/AR problems that can be solve using Triangles. In using Triangles to solve problems, we must first know how to solve for the missing parts of Triangles.

Some basics about Triangles:

- All Triangles have exactly 3 sides - usually lower case letters (a, b, and c)
- All Triangles have 3 interior angles - usually upper case letters (A, B, and C) which are opposite from the side with the same (lower case) letter
- The sum of the interior angles (between the sides) of the triangle of the Triangle equals 180 degrees
- Right Triangles have one of the interior angles equal to 90 degrees
 - $c^2 = a^2 + b^2$ or $c = \text{Sqr}(a^2 + b^2)$ is called the Pythagorean Theorem it is used to solve for the missing side of a Right Triangle
- The Law of Sines and the Law of Cosines are used to solve for the missing parts of any triangle



- Law of Sines: $\text{Sin}A/a = \text{Sin}B/b = \text{Sin}C/c$
 - $a = b * \text{Sin}(A) / \text{Sin}(B)$
 - $b = c * \text{Sin}(B) / \text{Sin}(C)$
 - $c = a * \text{Sin}(C) / \text{Sin}(A)$
- Law of Cosines:
 - $a^2 = b^2 + c^2 - 2bc * \text{Cos}(A)$
 - $b^2 = a^2 + c^2 - 2ac * \text{Cos}(B)$
 - $c^2 = a^2 + b^2 - 2ab * \text{Cos}(C)$

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 17 is a screen capture from REC-TEC with labels identifying the components of the triangles shown in the graphics.

Figure 17: Vectors (EDR-Momentum) with Labels

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
 22.7581 = Abs(12.06 / Cos(58 + Abs(0)))

DV2 = DV1 * (W1 / W2)
 34.1372 = 22.7581 * (3000 / 2000)

AngleC = 180 - (A3 + PDOF1)
 82 = 180 - (40 + 58)

AngleA = A2 - A4
 65 = 90 - 25

ALPHA2 = 180 - (PDOF1 + A2)
 32 = 180 - (58 + 90)

PDOF1 (LM) = 58

Adjustment Angle = 0

Angle2 (Degrees): 90

Angle3 (Degrees): 40

Angle4 (Degrees): 25

The diagram illustrates a vector triangle for momentum triangulation. A horizontal red vector V1 points to the right. A vertical green vector V2 points upwards. A red vector V3 points up and to the right. A green vector V4 points up and to the right, below V3. A red vector DV1 points up and to the right, above V3. A green vector DV2 points up and to the right, above DV1. A red vector PDOF1 points to the right. A green vector PDOF2 points upwards. Angles A3, A4, AngleA, AngleB, and AngleC are marked between various vectors. A coordinate system with +X and +Y axes is shown in the bottom left.

AngleB = 180 - (ALPHA2 + AngleA)
 83 = 180 - (32 + 65)

V1 = DV1 * Sin(AngleC) / Sin(A3)
 35.0608 = 22.7581 * Sin(82) / Sin(40)

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
 37.3855 = 34.1372 * Sin(83) / Sin(65)

V3 = DV1 * Sin(PDOF1) / Sin(A3)
 30.0255 = 22.7581 * Sin(58) / Sin(40)

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
 19.9601 = 34.1372 * Sin(180 - (65 + 83)) / Sin(65)

PDOF2 (LM) = -32

<input type="checkbox"/> DV1 = 22.7581 M/H	<input type="checkbox"/> DV2 = 34.1372 M/H	<input type="checkbox"/> V1 = 35.0608 M/H	<input type="checkbox"/> V2 = 37.3855 M/H	<input type="checkbox"/> V3 = 30.0255 M/H	<input type="checkbox"/> V4 = 19.9601 M/H
DV1 = 33.3786 f/s	DV2 = 50.068 f/s	V1 = 51.4226 f/s	V2 = 54.8321 f/s	V3 = 44.0374 f/s	V4 = 29.2748 f/s

Lng. DeltaV (X):	M/H	12.06
Lat. DeltaV (Y):	M/H	19.3
PDOF1 (Degrees):		58

Angle2 (Degrees):	90
Angle3 (Degrees):	40
Angle4 (Degrees):	25

Slip Angle (Deg):		
Weight (1):	lbs	3000
Weight (2):	lbs	2000

Iteration/FDA **Formulae*** **N**

>DLM **>LMO** **>PFL** **C**

Open .VEC File **Save .VEC File**

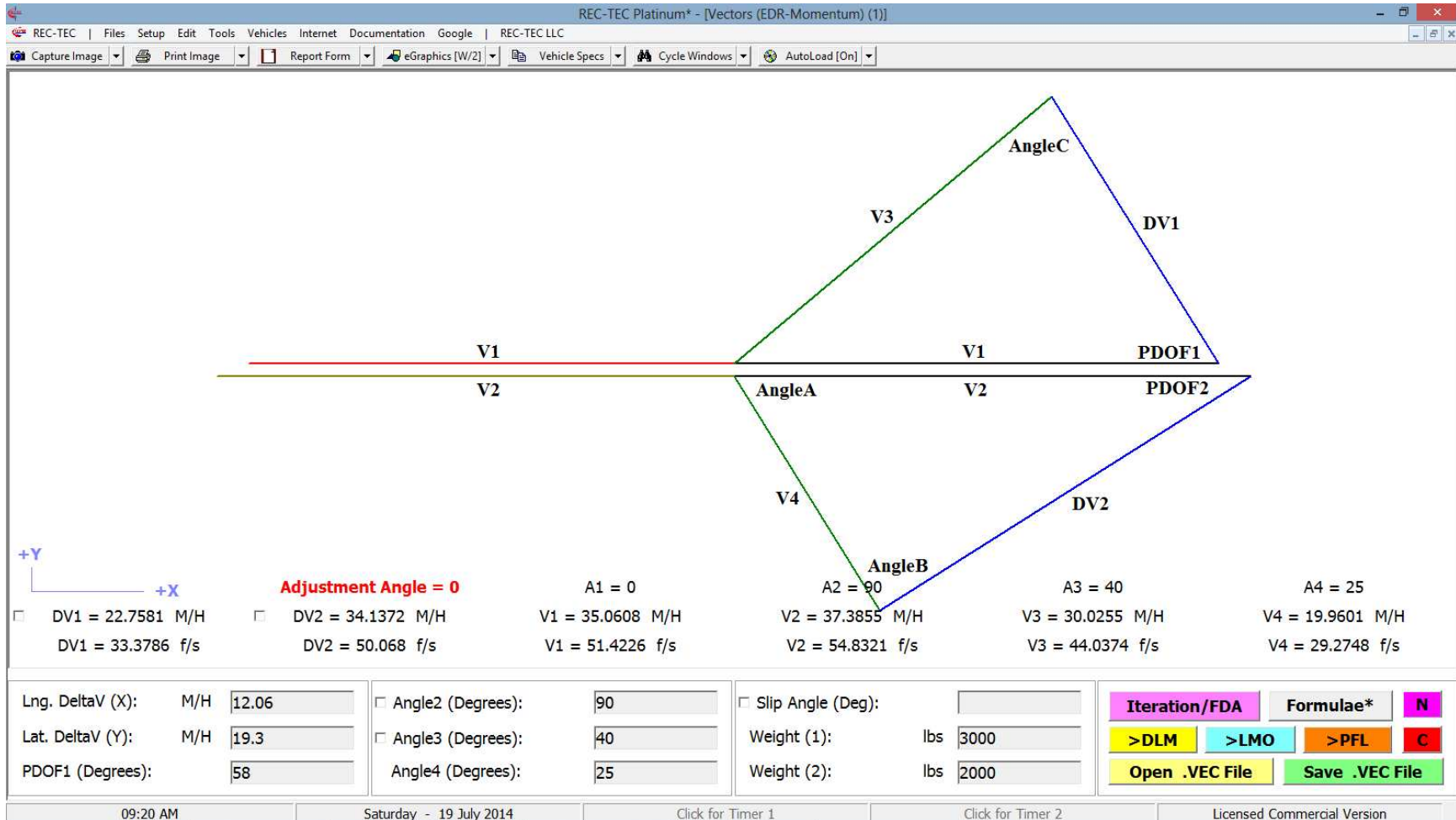
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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 18 is a screen capture from REC-TEC with labels identifying the components of the triangles shown in the graphics.

Figure 18: Vectors (EDR-Momentum) with Labels



Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Solutions:

Figure 19: Vectors (EDR-Momentum) - DeltaV1 computation

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]

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DeltaV1 (Lat)
19.3 M/H

PDOF1 Angle (Deg)
58 degrees

DeltaV1 (Lng) = 12.06 M/H

$DV1 (Lng) = DV1 * \cos(PDOF1 + \text{Abs}(\text{SlipAngle}))$
 $DV1 (Lng) = 22.7581 * \cos(58)$

Resultant DeltaV1 = 22.7581 M/H

$DV1 (Lat) = \text{Sqr}(DV1^2 - DV1 (Lng)^2)$
 $DV1 (Lat) = \text{Sqr}(517.9349 - 145.4436)$

+Y
+X

DV1 = 22.7581 M/H
 DV1 = 33.3786 f/s

Lng. DeltaV (X):	M/H	<input type="text" value="12.06"/>	<input type="checkbox"/> Angle2 (Degrees):	<input type="text" value="90"/>	<input type="checkbox"/> Slip Angle (Deg):	<input type="text"/>	Iteration/FDA	Formulae*	N	
Lat. DeltaV (Y):	M/H	<input type="text" value="19.3"/>	<input type="checkbox"/> Angle3 (Degrees):	<input type="text" value="40"/>	Weight (1):	lbs <input type="text" value="3000"/>	>DLM	>LMO	>PFL	C
PDOF1 (Degrees):		<input type="text" value="58"/>	Angle4 (Degrees):	<input type="text" value="25"/>	Weight (2):	lbs <input type="text" value="2000"/>	Open .VEC File	Save .VEC File		

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Vectors (EDR-Momentum) Solution for DV1

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 20: Triangle Solver - DeltaV1 Solution

REC-TEC Platinum* - [TRI (1) - Triangle Solver]

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Capture Image Print Image Report Form eGraphics [W/2] Vehicle Specs Cycle Windows AutoLoad [On]

Triangle Solver - Input (3 of 6)

Angle A

Angle B

Angle C

Side a

Side b

Side c

Open .TRI File Save .TRI File N

Right Scalene Triangle

Triangle Height	19.3
Perimeter (a+ b+ c)	54.1181
Area (.5*Base*Height)	116.379
C1 (Pt. H to Pt. 1)	0
C2 (Pt. H to Pt. 2)	19.3
Inscribed Radius	4.3009
Circumscribed Radius	11.379
Centroid (X)	4.02
Centroid (Y)	6.4333

Triangle Base

Side a	12.06	Side b	22.7581	Side c	19.3
--------	-------	--------	---------	--------	------

Angle A	Deg: 32	Sin: .5299	Cos: .848	Tan: .6248	Rad: .5585
Angle B	Deg: 90	Sin: 1	Cos: 0	Tan: Infinity	Rad: 1.5707
Angle C	Deg: 57.9999	Sin: .848	Cos: .5299	Tan: 1.6003	Rad: 1.0122

Angle C1	Deg: 57.9999	Sin: .848	Cos: .5299	Tan: 1.6003	Rad: 1.0122
Angle C2	Deg: 0	Sin: 0	Cos: 1	Tan: 1	Rad: 0
Angle ABC	Deg: 180	Sin: 0	Cos: -1	Tan: 0	Rad: 3.1415

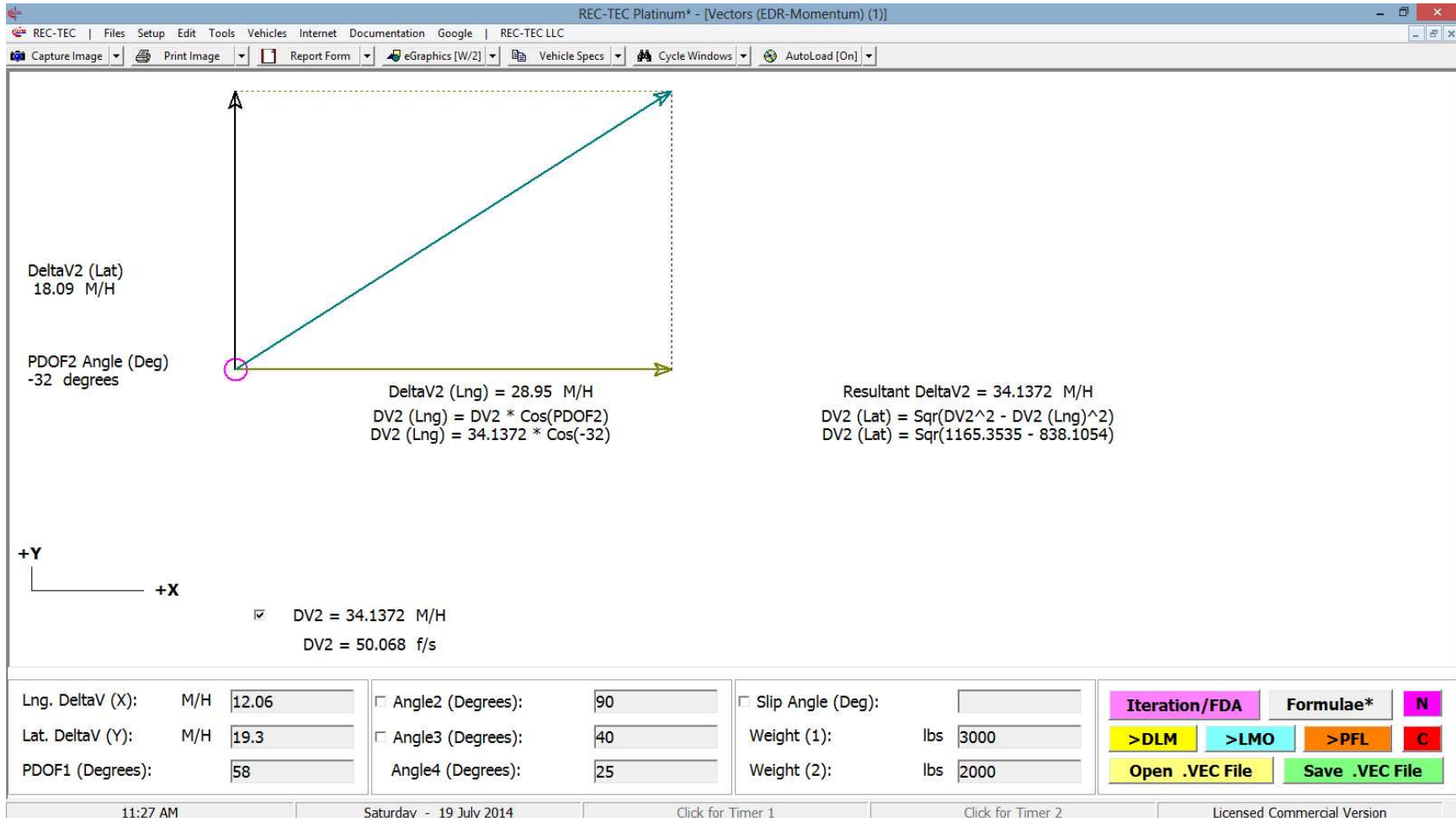
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Triangle Solution for DV1

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 21: Vectors (EDR-Momentum) - DeltaV2 computation



Vectors (EDR-Momentum) Solution for DV2

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 22: Triangle Solver - DeltaV2 Solution

REC-TEC Platinum* - [TRI (1) - Triangle Solver]

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Capture Image Print Image Report Form eGraphics [W/2] Vehicle Specs Cycle Windows AutoLoad [On]

Triangle Solver - Input (3 of 6)

Angle A

Angle B

Angle C

Side a

Side b

Side c

Open .TRI File Save .TRI File N

Right Scalene Triangle

Triangle Height 18.09

Perimeter (a+ b+ c) 81.1772

Area (.5*Base*Height) 261.8527

C1 (Pt. H to Pt. 1) 9.5862

C2 (Pt. H to Pt. 2) 24.5509

Inscribed Radius 6.4513

Circumscribed Radius 17.0686

Centroid (X) 6.03

Centroid (Y) 9.65

Triangle Base

Side a 18.09 Side b 28.95 Side c 34.1372

Angle A	Deg: 32	Sin: .5299	Cos: .848	Tan: .6248	Rad: .5585
Angle B	Deg: 57.9999	Sin: .848	Cos: .5299	Tan: 1.6003	Rad: 1.0122
Angle C	Deg: 90	Sin: 1	Cos: 0	Tan: Infinity	Rad: 1.5707

Angle C1	Deg: 57.9999	Sin: .848	Cos: .5299	Tan: 1.6003	Rad: 1.0122
Angle C2	Deg: 32	Sin: .5299	Cos: .848	Tan: .6248	Rad: .5585
Angle ABC	Deg: 180	Sin: 0	Cos: -1	Tan: 0	Rad: 3.1415

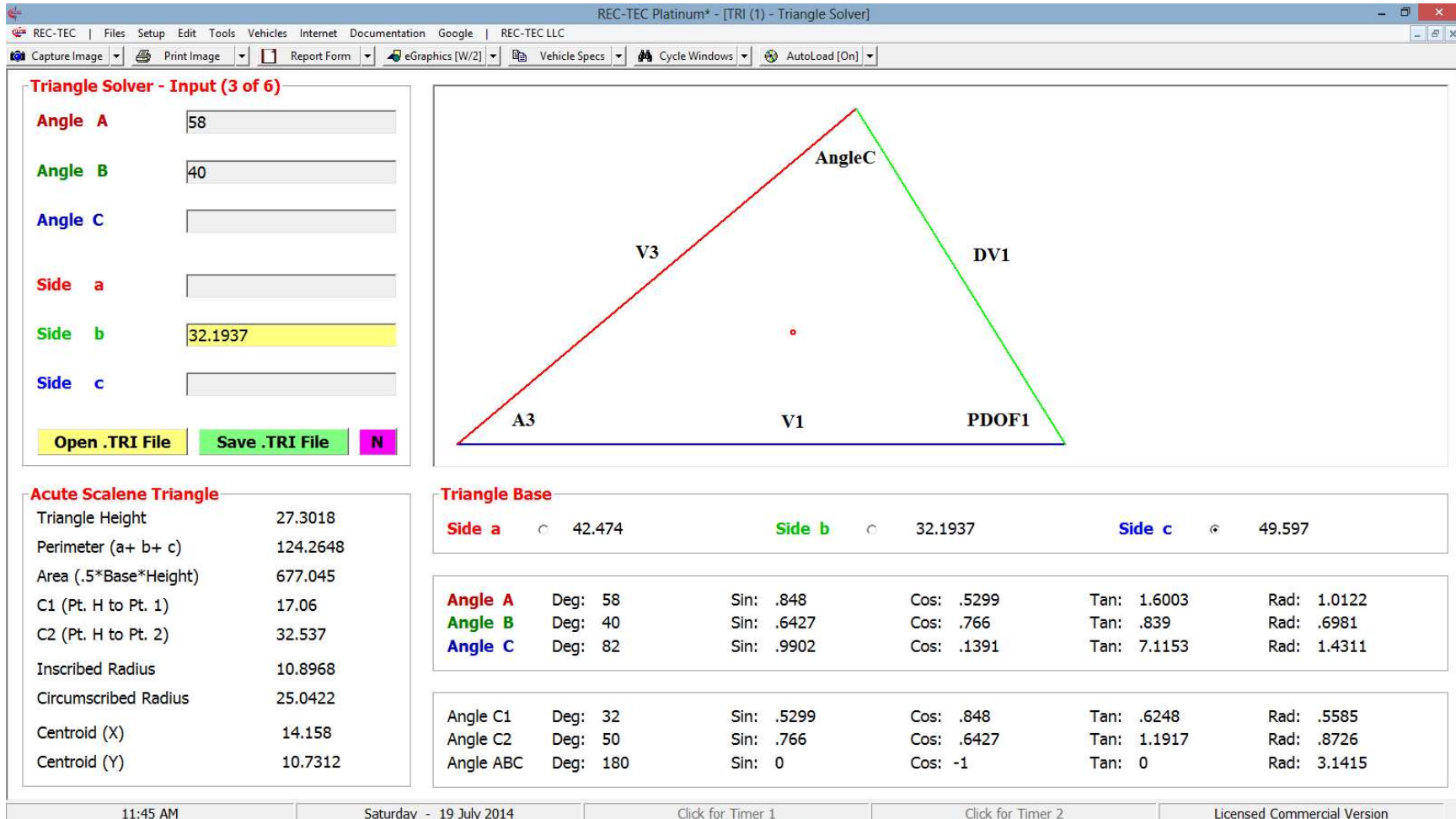
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Triangle Solution for DV2

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 23: Triangle Solver - Solution for V1, V3, and AngleC



Triangle Solution for V1, V3, and AngleC
Known: PDOF1 = 58, A3 = 40, and DV1 = 32.1937
Solution: V1 = 49.597, V3 = 42.474, and AngleC = 82

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 24: Triangle Solver - Solution for V2, V4, and AngleB

Triangle Solver - Input (3 of 6)

Angle A: 65
 Angle B:
 Angle C: 32
 Side a: 34.1372
 Side b:
 Side c:
 Open .TRI File Save .TRI File N

Acute Scalene Triangle

Triangle Height	18.0899
Perimeter (a+ b+ c)	91.4827
Area (.5*Base*Height)	338.1508
C1 (Pt. H to Pt. 1)	4.1602
C2 (Pt. H to Pt. 2)	15.7997
Inscribed Radius	7.3926
Circumscribed Radius	18.8331
Centroid (X)	11.379
Centroid (Y)	6.6533

Triangle Base

Side a	34.1372	Side b	37.3854	Side c	19.96
--------	---------	--------	---------	--------	-------

Angle A	Deg: 65	Sin: .9063	Cos: .4226	Tan: 2.1445	Rad: 1.1344
Angle B	Deg: 83	Sin: .9925	Cos: .1218	Tan: 8.1443	Rad: 1.4486
Angle C	Deg: 32	Sin: .5299	Cos: .848	Tan: .6248	Rad: .5585

Angle C1	Deg: 25	Sin: .4226	Cos: .9063	Tan: .4663	Rad: .4363
Angle C2	Deg: 7	Sin: .1218	Cos: .9925	Tan: .1227	Rad: .1221
Angle ABC	Deg: 180	Sin: 0	Cos: -1	Tan: 0	Rad: 3.1415

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Triangle Solution for V2, V4, and AngleB
Known: AngleA = 65, PDOF2 = 32, and DV2 = 34.1372
Solution: V2 = 37.3854, V4 = 19.96, and AngleB = 83

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 25: Vectors (EDR-Momentum) Solution

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]
REC-TEC LLC

Capture Image
Print Image
Report Form
eGraphics [W/2]
Vehicle Specs
Cycle Windows
AutoLoad [On]

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
 22.7581 = Abs(12.06 / Cos(58 + Abs(0)))

DV2 = DV1 * (W1 / W2)
 34.1372 = 22.7581 * (3000 / 2000)

AngleC = 180 - (A3 + PDOF1)
 82 = 180 - (40 + 58)

AngleA = A2 - A4
 65 = 90 - 25

ALPHA2 = 180 - (PDOF1 + A2)
 32 = 180 - (58 + 90)

PDOF1 (LM) = 58

Adjustment Angle = 0

+Y

<input type="checkbox"/> DV1 = 22.7581 M/H	<input type="checkbox"/> DV2 = 34.1372 M/H	<input type="checkbox"/> V1 = 35.0608 M/H	<input type="checkbox"/> V2 = 37.3855 M/H	<input type="checkbox"/> V3 = 30.0255 M/H	<input type="checkbox"/> V4 = 19.9601 M/H
DV1 = 33.3786 f/s	DV2 = 50.068 f/s	V1 = 51.4226 f/s	V2 = 54.8321 f/s	V3 = 44.0374 f/s	V4 = 29.2748 f/s

AngleB = 180 - (ALPHA2 + AngleA)
 83 = 180 - (32 + 65)

V1 = DV1 * Sin(AngleC) / Sin(A3)
 35.0608 = 22.7581 * Sin(82) / Sin(40)

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
 37.3855 = 34.1372 * Sin(83) / Sin(65)

V3 = DV1 * Sin(PDOF1) / Sin(A3)
 30.0255 = 22.7581 * Sin(58) / Sin(40)

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
 19.9601 = 34.1372 * Sin(180 - (65 + 83)) / Sin(65)

PDOF2 (LM) = -32

Lng. DeltaV (X): M/H <input type="text" value="12.06"/>	Angle2 (Degrees): <input type="text" value="90"/>	Slip Angle (Deg): <input type="text"/>	Iteration/FDA <input type="text" value="N"/>
Lat. DeltaV (Y): M/H <input type="text" value="19.3"/>	Angle3 (Degrees): <input type="text" value="40"/>	Weight (1): lbs <input type="text" value="3000"/>	>DLM >LMO >PFL C
PDOF1 (Degrees): <input type="text" value="58"/>	Angle4 (Degrees): <input type="text" value="25"/>	Weight (2): lbs <input type="text" value="2000"/>	Open .VEC File Save .VEC File

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Vectors (EDR-Momentum) Solution

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 26: Vectors (EDR-Momentum) Solution

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]
REC-TEC LLC

Capture Image
Print Image
Report Form
eGraphics [W/2]
Vehicle Specs
Cycle Windows
AutoLoad [On]

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
 22.7581 = Abs(12.06 / Cos(58 + Abs(0)))

DV2 = DV1 * (W1 / W2)
 34.1372 = 22.7581 * (3000 / 2000)

AngleC = 180 - (A3 + PDOF1)
 82 = 180 - (40 + 58)

AngleA = A2 - A4
 65 = 90 - 25

ALPHA2 = 180 - (PDOF1 + A2)
 32 = 180 - (58 + 90)

PDOF1 (LM) = 58

Adjustment Angle = 0

AngleB = 180 - (ALPHA2 + AngleA)
 83 = 180 - (32 + 65)

V1 = DV1 * Sin(AngleC) / Sin(A3)
 35.0608 = 22.7581 * Sin(82) / Sin(40)

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
 37.3855 = 34.1372 * Sin(83) / Sin(65)

V3 = DV1 * Sin(PDOF1) / Sin(A3)
 30.0255 = 22.7581 * Sin(58) / Sin(40)

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
 19.9601 = 34.1372 * Sin(180 - (65 + 83)) / Sin(65)

PDOF2 (LM) = -32

+Y

+X

A1 = 0 A2 = 90 A3 = 40 A4 = 25

V1 = 35.0608 M/H V2 = 37.3855 M/H V3 = 30.0255 M/H V4 = 19.9601 M/H

V1 = 51.4226 f/s V2 = 54.8321 f/s V3 = 44.0374 f/s V4 = 29.2748 f/s

Lng. DeltaV (X):	M/H	12.06
Lat. DeltaV (Y):	M/H	19.3
PDOF1 (Degrees):		58

Angle2 (Degrees):	90
Angle3 (Degrees):	40
Angle4 (Degrees):	25

Slip Angle (Deg):		
Weight (1):	lbs	3000
Weight (2):	lbs	2000

Iteration/FDA **Formulae*** **N**

>DLM >LMO >PFL C

Open .VEC File Save .VEC File

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Vectors (EDR-Momentum) Solution

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Example 4 – Vectors (EDR-Momentum)

Note: In late 2011 this module was upgraded. The upgraded Vector module is now capable of sending its Momentum solution directly to the 360 Linear Momentum module using the [**> LMO**] button. Two Checkboxes have also been added in front of the DV1 and DV2 solutions. Placing a check in one of these boxes will bring up the Solution Diagram for the corresponding PDOF/DeltaV. Un-checking the box will return the user to the Momentum Vector diagram. Using the [Esc] key will show the Longitudinal and Lateral components used to arrive at the PDOF solution if that methodology was employed in the solution. The ToolTips (place cursor over the inputs or Checkboxes) will describe the effect these actions will have on the modules displays.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 28 uses an 80-degree approach angle for Vehicle 2.

Figure 28: Vectors (EDR-Momentum) Solution - A2 = 80 degrees

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]

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Capture Image Print Image Report Form eGraphics [W/2] Vehicle Specs Cycle Windows AutoLoad [On]

$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$
 $22.7581 = \text{Abs}(12.06 / \text{Cos}(58 + \text{Abs}(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.1372 = 22.7581 * (3000 / 2000)$

$\text{AngleC} = 180 - (A3 + \text{PDOF1})$
 $82 = 180 - (40 + 58)$

$\text{AngleA} = A2 - A4$
 $55 = 80 - 25$

$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$
 $42 = 180 - (58 + 80)$

PDOF1 (LM) = 58

+Y
 +X

Adjustment Angle = 0

A1 = 0
 A2 = 80
 A3 = 40
 A4 = 25

DV1 = 22.7581 M/H
 DV1 = 33.3786 f/s

DV2 = 34.1372 M/H
 DV2 = 50.068 f/s

V1 = 35.0608 M/H
 V1 = 51.4226 f/s

V2 = 41.3632 M/H
 V2 = 60.6661 f/s

V3 = 30.0255 M/H
 V3 = 44.0374 f/s

V4 = 27.8852 M/H
 V4 = 40.8984 f/s

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $83 = 180 - (42 + 55)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $35.0608 = 22.7581 * \text{Sin}(82) / \text{Sin}(40)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $41.3632 = 34.1372 * \text{Sin}(83) / \text{Sin}(55)$

$V3 = DV1 * \text{Sin}(\text{PDOF1}) / \text{Sin}(A3)$
 $30.0255 = 22.7581 * \text{Sin}(58) / \text{Sin}(40)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$
 $27.8852 = 34.1372 * \text{Sin}(180 - (55 + 83)) / \text{Sin}(55)$

PDOF2 (LM) = -42

Lng. DeltaV (X): M/H 12.06
 Lat. DeltaV (Y): M/H 19.3
 PDOF1 (Degrees): 58

Angle2 (Degrees): 80
 Angle3 (Degrees): 40
 Angle4 (Degrees): 25

Slip Angle (Deg):
 Weight (1): lbs 3000
 Weight (2): lbs 2000

Iteration/FDA Formulae* N
 >DLM >LMO >PFL C
 Open .VEC File Save .VEC File

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 29 uses a 100-degree approach angle for Vehicle 2.

Figure 29: Vectors (EDR-Momentum) Solution - A2 = 100 degrees

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]

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Capture Image Print Image Report Form eGraphics [W/2] Vehicle Specs Cycle Windows AutoLoad [On]

$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$
 $22.7581 = \text{Abs}(12.06 / \text{Cos}(58 + \text{Abs}(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.1372 = 22.7581 * (3000 / 2000)$

$\text{AngleC} = 180 - (A3 + \text{PDOF1})$
 $82 = 180 - (40 + 58)$

$\text{AngleA} = A2 - A4$
 $75 = 100 - 25$

$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$
 $22 = 180 - (58 + 100)$

PDOF1 (LM) = 58

PDOF2 (LM) = -22

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $83 = 180 - (22 + 75)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $35.0608 = 22.7581 * \text{Sin}(82) / \text{Sin}(40)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $35.078 = 34.1372 * \text{Sin}(83) / \text{Sin}(75)$

$V3 = DV1 * \text{Sin}(\text{PDOF1}) / \text{Sin}(A3)$
 $30.0255 = 22.7581 * \text{Sin}(58) / \text{Sin}(40)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$
 $13.2391 = 34.1372 * \text{Sin}(180 - (75 + 83)) / \text{Sin}(75)$

Adjustment Angle = 0

A1 = 0	A2 = 100	A3 = 40	A4 = 25
DV1 = 22.7581 M/H DV1 = 33.3786 f/s	DV2 = 34.1372 M/H DV2 = 50.068 f/s	V1 = 35.0608 M/H V1 = 51.4226 f/s	V2 = 35.078 M/H V2 = 51.4478 f/s
V3 = 30.0255 M/H V3 = 44.0374 f/s	V4 = 13.2391 M/H V4 = 19.4174 f/s		

Lng. DeltaV (X): M/H 12.06
 Lat. DeltaV (Y): M/H 19.3
 PDOF1 (Degrees): 58

Angle2 (Degrees): 100
 Angle3 (Degrees): 40
 Angle4 (Degrees): 25

Slip Angle (Deg):
 Weight (1): lbs 3000
 Weight (2): lbs 2000

Iteration/FDA Formulae* N
 >DLM >LMO >PFL C
 Open .VEC File Save .VEC File

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 30 uses a 10-degree Slip Angle to calculate DV1 with Angle 2 = 90 degrees.

Figure 30: Vectors (EDR-Momentum) Solution - 10 degree Slip Angle with A2 = 90 degrees

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
 32.1937 = Abs(12.06 / Cos(58 + Abs(10)))

DV2 = DV1 * (W1 / W2)
 48.2906 = 32.1937 * (3000 / 2000)

AngleC = 180 - (A3 + PDOF1)
 82 = 180 - (40 + 58)

AngleA = A2 - A4
 65 = 90 - 25

ALPHA2 = 180 - (PDOF1 + A2)
 32 = 180 - (58 + 90)

PDOF1 (LM) = 58

Adjustment Angle = 0

AngleB = 180 - (ALPHA2 + AngleA)
 83 = 180 - (32 + 65)

V1 = DV1 * Sin(AngleC) / Sin(A3)
 49.5972 = 32.1937 * Sin(82) / Sin(40)

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
 52.8856 = 48.2906 * Sin(83) / Sin(65)

V3 = DV1 * Sin(PDOF1) / Sin(A3)
 42.4741 = 32.1937 * Sin(58) / Sin(40)

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
 28.2356 = 48.2906 * Sin(180 - (65 + 83)) / Sin(65)

PDOF2 (LM) = -32

	+Y		+X				
<input type="checkbox"/> DV1 = 32.1937 M/H	<input type="checkbox"/> DV2 = 48.2906 M/H	V1 = 49.5972 M/H	A1 = 0	A2 = 90	A3 = 40	A4 = 25	
DV1 = 47.2175 f/s	DV2 = 70.8263 f/s	V1 = 72.7425 f/s		V2 = 77.5656 f/s	V3 = 62.2954 f/s	V4 = 41.4122 f/s	

Lng. DeltaV (X): M/H <input type="text" value="12.06"/>	Angle2 (Degrees): <input type="text" value="90"/>	Slip Angle (Deg): <input type="text" value="10"/>	Iteration/FDA <input type="text" value="N"/>
Lat. DeltaV (Y): M/H <input type="text" value="29.8495"/>	Angle3 (Degrees): <input type="text" value="40"/>	Weight (1): lbs <input type="text" value="3000"/>	>DLM <input type="text" value="C"/>
PDOF1 (Degrees): <input type="text" value="58"/>	Angle4 (Degrees): <input type="text" value="25"/>	Weight (2): lbs <input type="text" value="2000"/>	>LMO <input type="text" value=""/>
		>PFL <input type="text" value=""/>	
		Open .VEC File <input type="text" value=""/>	
		Save .VEC File <input type="text" value=""/>	

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 31 uses a 10-degree Slip Angle to calculate DV1 with Angle 2 at 90 degrees and with a Lateral DeltaV used to compute the PDOF angle of 58 degrees.

Figure 31: Vectors (EDR-Momentum) Delta V1 Solution - 10 degree Slip Angle with A2 = 90 degrees

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]

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Capture Image Print Image Report Form eGraphics [W/2] Vehicle Specs Cycle Windows AutoLoad [On]

DeltaV1 (Lat)
29.8495 M/H

PDOF1 Angle (Deg)
58 degrees

DeltaV1 (Lng) = 12.06 M/H

DV1 (Lng) = DV1 * Cos(PDOF1 + Abs(SlipAngle))
DV1 (Lng) = 32.1937 * Cos(68)

Resultant DeltaV1 = 32.1937 M/H

DV1 (Lat) = Sqr(DV1^2 - DV1 (Lng)^2)
DV1 (Lat) = Sqr(1036.439 - 145.4436)

+Y
+X

DV1 = 32.1937 M/H
DV1 = 47.2175 f/s

Lng. DeltaV (X):	M/H	12.06	<input type="checkbox"/> Angle2 (Degrees):	90	<input type="checkbox"/> Slip Angle (Deg):	10	Iteration/FDA	Formulae*	N	
Lat. DeltaV (Y):	M/H	29.8495	<input type="checkbox"/> Angle3 (Degrees):	40	Weight (1):	lbs	>DLM	>LMO	>PFL	C
PDOF1 (Degrees):		58	Angle4 (Degrees):	25	Weight (2):	lbs	2000	Open .VEC File	Save .VEC File	

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 31 shows the DV1 Vector Diagram with a Check in the DV1 Checkbox. The screen shows a PDOF1 of 58 degrees along with the 10-degree slip angle used in the computations.

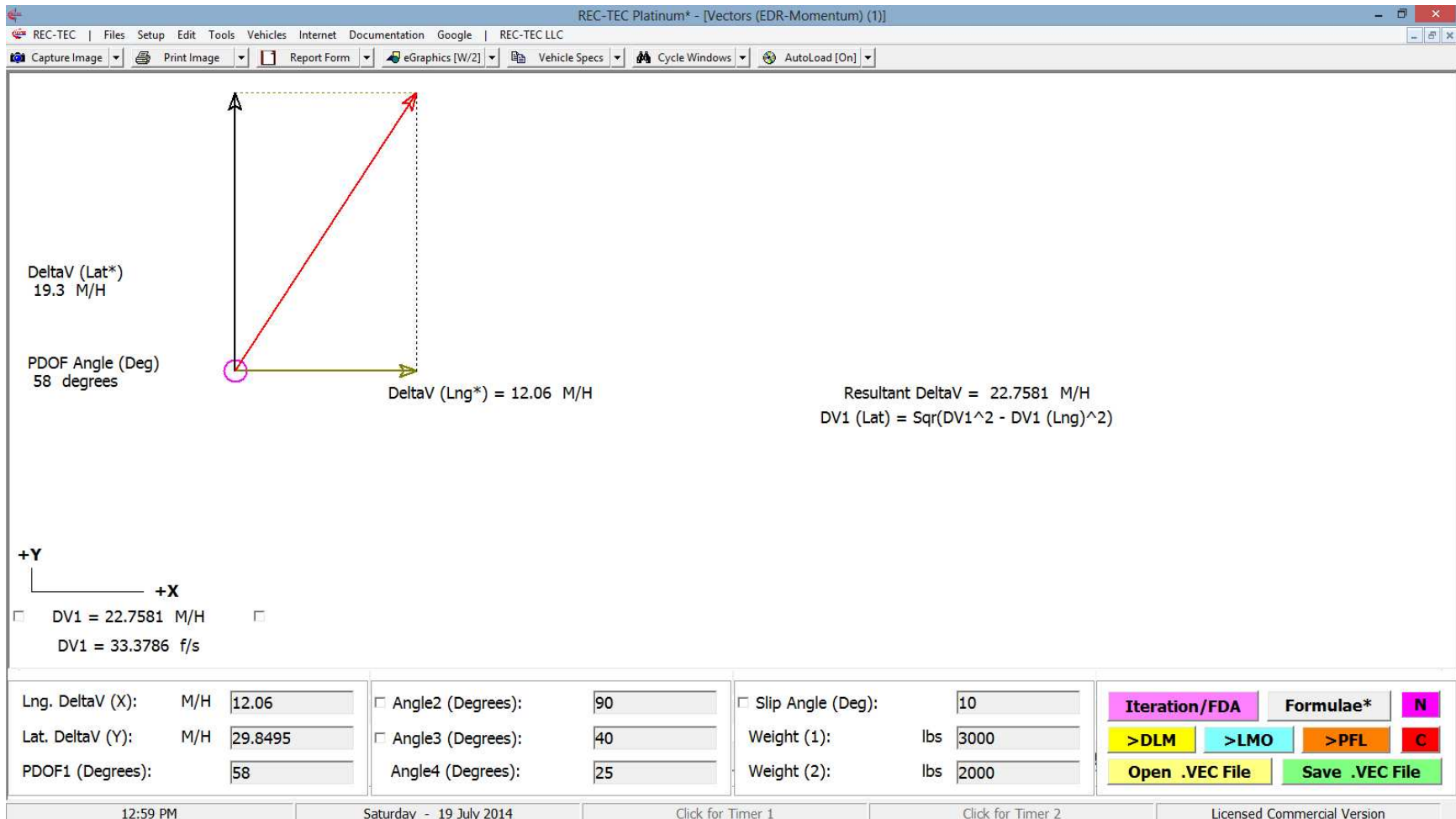
In order to see the information in the Vector Diagram shown in Figure 31, but without the Slip angle of 10 degrees, the 10 degrees could be removed from the Slip angle input label. This will alter the problem if the 10 degrees is not returned.

Another method is to use the [Esc] key, which brings up the data for the initial computation of 58 degrees based on the Lateral Input but does not account for the Slip angle (Figure 32). This does not put the problem at risk, as the 10 degree Slip angle has not be altered.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 32: Vectors (EDR-Momentum) Delta V1 Solution - 0 degree Slip Angle with A2 = 90 degrees



Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

A second [Esc] key returns the screen to the initial Momentum diagram (Figure 33).

Figure 33: Vectors (EDR-Momentum) Solution - Same as Figure 30

$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$
 $32.1937 = \text{Abs}(12.06 / \text{Cos}(58 + \text{Abs}(10)))$

$DV2 = DV1 * (W1 / W2)$
 $48.2906 = 32.1937 * (3000 / 2000)$

$\text{AngleC} = 180 - (A3 + \text{PDOF1})$
 $82 = 180 - (40 + 58)$

$\text{AngleA} = A2 - A4$
 $65 = 90 - 25$

$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$
 $32 = 180 - (58 + 90)$

PDOF1 (LM) = 58

Adjustment Angle = 0

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $83 = 180 - (32 + 65)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $49.5972 = 32.1937 * \text{Sin}(82) / \text{Sin}(40)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $52.8856 = 48.2906 * \text{Sin}(83) / \text{Sin}(65)$

$V3 = DV1 * \text{Sin}(\text{PDOF1}) / \text{Sin}(A3)$
 $42.4741 = 32.1937 * \text{Sin}(58) / \text{Sin}(40)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$
 $28.2356 = 48.2906 * \text{Sin}(180 - (65 + 83)) / \text{Sin}(65)$

PDOF2 (LM) = -32

	+Y		Adjustment Angle = 0		+X	
<input type="checkbox"/> DV1 = 32.1937 M/H	<input type="checkbox"/> DV2 = 48.2906 M/H	V1 = 49.5972 M/H	A1 = 0	A2 = 90	A3 = 40	A4 = 25
DV1 = 47.2175 f/s	DV2 = 70.8263 f/s	V1 = 72.7425 f/s		V2 = 77.5656 f/s	V3 = 62.2954 f/s	V4 = 41.4122 f/s

Lng. DeltaV (X):	M/H	<input type="text" value="12.06"/>
Lat. DeltaV (Y):	M/H	<input type="text" value="29.8495"/>
PDOF1 (Degrees):		<input type="text" value="58"/>

<input type="checkbox"/> Angle2 (Degrees):	<input type="text" value="90"/>
<input type="checkbox"/> Angle3 (Degrees):	<input type="text" value="40"/>
<input type="checkbox"/> Angle4 (Degrees):	<input type="text" value="25"/>

<input type="checkbox"/> Slip Angle (Deg):	<input type="text" value="10"/>
Weight (1):	lbs <input type="text" value="3000"/>
Weight (2):	lbs <input type="text" value="2000"/>

Iteration/FDA

Formulae*

N

>DLM

>LMO

>PFL

C

Open .VEC File

Save .VEC File

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Advanced Solutions:

In July of 2014, this module underwent a major upgrade and a name change to **Vectors (EDR-Momentum)**, to more accurately reflect the capabilities of the upgraded module.

If using the AutoLoad feature when the module is first called up after the version upgrade, the only noticeable changes are:

1. The name change for the Module
2. New blocks appear over the DV2, V1, V2, V3, and V4 solution blocks
 - a. Adjustment Angle
 - b. $A1 = 0$
 - c. $A2 = 55$
 - d. $A3 = 14.8641$
 - e. $A4 = 10$
3. Checkboxes are now in front of Angle2, Angle3 and Slip Angle
4. The 1<>2 button is no more.

All remaining Examples will use the following data except as noted:

Longitudinal DeltaV = -25.66 M/H

Lateral Delta V = 12.8298 M/H

Angle 1 = 0 degrees

Slip Angle = 0 degrees

Adjustment Angle = 0 Degrees or as Shown

Weight 1 = 3000

Weight 2 = 2500

Angle 2 = As Shown

Angle 3 = As Shown

Angle 4 = As Shown

A tour of the new features in the upgrade will start with Clicking on the Formulae* button.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

At first it may look like the Graphics are incorrect. This is the Graphics configuration for the LM-PDOF Lite module shown on the Vector screen.

Figure 34: Vectors (EDR-Momentum) Solution - Alternate Graphics

$DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))$
 $28.6886 = Abs(-25.66 / Cos(26.5646 + Abs(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.4263 = 28.6886 * (3000 / 2500)$

$AngleC = 180 - (A3 + PDOF1)$
 $138.5712 = 180 - (14.8641 + 26.5646)$

$AngleA = A2 - A4$
 $45 = 45 - 0$

$ALPHA2 = 180 - (PDOF1 + A2)$
 $108.4353 = 180 - (26.5646 + 45)$

PDOF1 (LM) = 26.5646

+Y

$AngleB = 180 - (ALPHA2 + AngleA)$
 $26.5646 = 180 - (108.4353 + 45)$

$V1 = DV1 * Sin(AngleC) / Sin(A3)$
 $73.9998 = 28.6886 * Sin(138.5712) / Sin(14.8641)$

$V2 = DV2 * Sin(AngleB) / Sin(AngleA)$
 $21.7728 = 34.4263 * Sin(26.5646) / Sin(45)$

$V3 = DV1 * Sin(PDOF1) / Sin(A3)$
 $50.0134 = 28.6886 * Sin(26.5646) / Sin(14.8641)$

$V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)$
 $46.1877 = 34.4263 * Sin(180 - (45 + 26.5646)) / Sin(45)$

PDOF2 (LM) = -108.4353

<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	V1 = 73.9998 M/H	V2 = 21.7728 M/H	V3 = 50.0134 M/H	V4 = 46.1877 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.533 f/s	V2 = 31.9335 f/s	V3 = 73.3529 f/s	V4 = 67.742 f/s

Lng. DeltaV (X): M/H

Lat. DeltaV (Y): M/H

PDOF1 (Degrees):

Angle2 (Degrees):

Angle3 (Degrees):

Angle4 (Degrees):

Slip Angle (Deg):

Weight (1): lbs

Weight (2): lbs

Iteration/FDA **Formulae*** **N**

>DLM **>LMO** **>PFL** **C**

Open .VEC File **Save .VEC File**

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Right clicking the mouse will restore the more familiar 360 LM configuration.

Figure 35: Vectors (EDR-Momentum) Solution - 360 LM Graphics

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]

$DV1 = \text{Abs}(DV1X / \text{Cos}(PDOF1 + \text{Abs}(\text{SlipAngle})))$
 $28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.4263 = 28.6886 * (3000 / 2500)$

$\text{AngleC} = 180 - (A3 + PDOF1)$
 $138.5712 = 180 - (14.8641 + 26.5646)$

$\text{AngleA} = A2 - A4$
 $45 = 45 - 0$

$\text{ALPHA2} = 180 - (PDOF1 + A2)$
 $108.4353 = 180 - (26.5646 + 45)$

PDOF1 (LM) = 26.5646

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $26.5646 = 180 - (108.4353 + 45)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $73.9998 = 28.6886 * \text{Sin}(138.5712) / \text{Sin}(14.8641)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $21.7728 = 34.4263 * \text{Sin}(26.5646) / \text{Sin}(45)$

$V3 = DV1 * \text{Sin}(PDOF1) / \text{Sin}(A3)$
 $50.0134 = 28.6886 * \text{Sin}(26.5646) / \text{Sin}(14.8641)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA})$
 $46.1877 = 34.4263 * \text{Sin}(180 - (45 + 26.5646)) / \text{Sin}(45)$

PDOF2 (LM) = -108.4353

+Y	+X	Adjustment Angle = 0	A1 = 0	A2 = 45	A3 = 14.8641	A4 = 0
<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H		V1 = 73.9998 M/H	V2 = 21.7728 M/H	V3 = 50.0134 M/H	V4 = 46.1877 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s		V1 = 108.533 f/s	V2 = 31.9335 f/s	V3 = 73.3529 f/s	V4 = 67.742 f/s

Lng. DeltaV (X): M/H	<input type="text" value="-25.66"/>	<input type="checkbox"/> Angle2 (Degrees):	<input type="text" value="45"/>	<input type="checkbox"/> Slip Angle (Deg):	<input type="text"/>
Lat. DeltaV (Y): M/H	<input type="text" value="12.8298"/>	<input type="checkbox"/> Angle3 (Degrees):	<input type="text" value="14.8641"/>	Weight (1): lbs	<input type="text" value="3000"/>
PDOF1 (Degrees):	<input type="text" value="26.5646"/>	<input type="checkbox"/> Angle4 (Degrees):	<input type="text" value="0"/>	Weight (2): lbs	<input type="text" value="2500"/>

Iteration/FDA	Formulae*	N
>DLM	>LMO	>PFL
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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Time to show where the Adjustment Angle comes from. Notice the Checkbox in front of Slip Angle? Click on it and Slip Angle changes to Adjustment Angle and you will notice it is set to 0.

Figure 36: Vectors (EDR-Momentum) Solution - Adjustment Angle

The screenshot displays the REC-TEC Platinum software interface for solving EDR-Momentum problems. The main window shows a series of calculations for determining vehicle velocities (V1-V4) and angles (AngleA-D) based on input parameters like PDOF1, PDOF2, and Adjustment Angle. A central diagram illustrates the vector relationships between the vehicles and their respective velocity vectors.

Calculations:

$$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$$

$$28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$$

$$DV2 = DV1 * (W1 / W2)$$

$$34.4263 = 28.6886 * (3000 / 2500)$$

$$\text{AngleC} = 180 - (A3 + \text{PDOF1})$$

$$138.5712 = 180 - (14.8641 + 26.5646)$$

$$\text{AngleA} = A2 - A4$$

$$45 = 45 - 0$$

$$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$$

$$108.4353 = 180 - (26.5646 + 45)$$

$$\text{PDOF1 (LM)} = 26.5646$$

$$\text{PDOF2 (LM)} = -108.4353$$

$$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$$

$$26.5646 = 180 - (108.4353 + 45)$$

$$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$$

$$73.9998 = 28.6886 * \text{Sin}(138.5712) / \text{Sin}(14.8641)$$

$$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$$

$$21.7728 = 34.4263 * \text{Sin}(26.5646) / \text{Sin}(45)$$

$$V3 = DV1 * \text{Sin}(\text{PDOF1}) / \text{Sin}(A3)$$

$$50.0134 = 28.6886 * \text{Sin}(26.5646) / \text{Sin}(14.8641)$$

$$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$$

$$46.1877 = 34.4263 * \text{Sin}(180 - (45 + 26.5646)) / \text{Sin}(45)$$

Results:

<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	V1 = 73.9998 M/H	V2 = 21.7728 M/H	V3 = 50.0134 M/H	V4 = 46.1877 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.533 f/s	V2 = 31.9335 f/s	V3 = 73.3529 f/s	V4 = 67.742 f/s

Input Parameters:

- Lng. DeltaV (X): M/H -25.66
- Lat. DeltaV (Y): M/H 12.8298
- PDOF1 (Degrees): 26.5646
- Angle2 (Degrees): 45
- Angle3 (Degrees): 14.8641
- Angle4 (Degrees): 0
- Adjustment Angle: 0
- Weight (1): lbs 3000
- Weight (2): lbs 2500

Buttons: Iteration/FDA, Formulae*, N, >DLM, >LMO, >PFL, C, Open .VEC File, Save .VEC File

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Change the Adjustment Angle to 10 degrees. Notice that it has not changed the base angles (below the Graphics Screen) to the Angles shown in red on the Graphics screen. We will come back to this later as it is a Major feature critical to the accuracy of the rest of the upgrades.

Figure 37: Vectors (EDR-Momentum) Solution - Adjustment Angle = 10 degrees

The screenshot displays the REC-TEC Platinum* software interface for solving vector problems. The main window shows a series of calculations for determining velocity components and angles based on an adjustment angle of 10 degrees. A central diagram illustrates a vector triangle with a horizontal red vector, a green vector, and a blue vector, with dashed lines indicating projections and angles.

Calculations:

$$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$$

$$28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$$

$$DV2 = DV1 * (W1 / W2)$$

$$34.4263 = 28.6886 * (3000 / 2500)$$

$$\text{AngleC} = 180 - (A3 + \text{PDOF1})$$

$$138.5712 = 180 - (14.8641 + 26.5646)$$

$$\text{AngleA} = A2 - A4$$

$$45 = 55 - 10$$

$$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$$

$$98.4353 = 180 - (26.5646 + 55)$$

$$\text{PDOF1 (LM)} = 26.5646$$

$$\text{PDOF2 (LM)} = -98.4353$$

$$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$$

$$36.5646 = 180 - (98.4353 + 45)$$

$$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$$

$$73.9998 = 28.6886 * \text{Sin}(138.5712) / \text{Sin}(14.8641)$$

$$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$$

$$29.0038 = 34.4263 * \text{Sin}(36.5646) / \text{Sin}(45)$$

$$V3 = DV1 * \text{Sin}(\text{PDOF1}) / \text{Sin}(A3)$$

$$50.0134 = 28.6886 * \text{Sin}(26.5646) / \text{Sin}(14.8641)$$

$$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$$

$$48.1595 = 34.4263 * \text{Sin}(180 - (45 + 36.5646)) / \text{Sin}(45)$$

Results:

Adjustment Angle = 10	A1 = 0	A2 = 55	A3 = 14.8641	A4 = 10	
DV1 = 28.6886 M/H	DV2 = 34.4263 M/H	V1 = 73.9998 M/H	V2 = 29.0038 M/H	V3 = 50.0134 M/H	V4 = 48.1595 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.533 f/s	V2 = 42.539 f/s	V3 = 73.3529 f/s	V4 = 70.634 f/s

Input Parameters:

Lng. DeltaV (X): M/H	-25.66	Angle2 (Degrees):	45	Adjustment Angle:	10	Iteration/FDA	Formulæ*	N	
Lat. DeltaV (Y): M/H	12.8298	Angle3 (Degrees):	14.8641	Weight (1): lbs	3000	>DLM	>LMO	>PFL	C
PDOF1 (Degrees):	26.5646	Angle4 (Degrees):	0	Weight (2): lbs	2500	Open .VEC File	Save .VEC File		

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Notice that there is a Checkbox in front of the Angle2 input line below the Graphics.

Figure 38: Vectors (EDR-Momentum) Solution - V1 Speed Input

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
 28.6886 = Abs(-25.66 / Cos(26.5646 + Abs(0)))

DV2 = DV1 * (W1 / W2)
 34.4263 = 28.6886 * (3000 / 2500)

AngleC = 180 - (A3 + PDOF1)
 138.5712 = 180 - (14.864 + 26.5646)

AngleA = A2 - A4
 45 = 45 - 0

ALPHA2 = 180 - (PDOF1 + A2)
 108.4353 = 180 - (26.5646 + 45)

PDOF1 (LM) = 26.5646

AngleB = 180 - (ALPHA2 + AngleA)
 26.5646 = 180 - (108.4353 + 45)

V1 = Input Variable

74 = Input Variable

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
 21.7728 = 34.4263 * Sin(26.5646) / Sin(45)

V3 = Sqr(V1 ^ 2 + DV1 ^ 2 - (2 * V1 * DV1 * Cos(PDOF1)))
50.0135 = Sqr(5476 + 823.0357 - 2 * 74 * 28.6886 * Cos(26.5646))

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
 46.1877 = 34.4263 * Sin(180 - (45 + 26.5646)) / Sin(45)

PDOF2 (LM) = -108.4353

+Y	+X	Adjustment Angle = N/A	A1 = 0	A2 = 45	A3 = 14.864	A4 = 0
<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	<input type="checkbox"/> V1 = 74 M/H	<input type="checkbox"/> V2 = 21.7728 M/H	<input type="checkbox"/> V3 = 50.0135 M/H	<input type="checkbox"/> V4 = 46.1877 M/H	
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5333 f/s	V2 = 31.9335 f/s	V3 = 73.3532 f/s	V4 = 67.742 f/s	

Lng. DeltaV (X): M/H

Lat. DeltaV (Y): M/H

PDOF1 (Degrees):

Speed V1 (M/H):

Angle Change (A2 to A4):

Adjustment Angle:

Weight (1): lbs

Weight (2): lbs

Iteration/FDA **Formulae*** **N**

>DLM **>LMO** **>PFL** **C**

Open .VEC File **Save .VEC File**

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Clicking on that Checkbox brings up an Input for the V1 speed which should show 74 M/H if that is the Primary input. A keen eye will notice that some of the Formulae have changed along with the data. The Input block asking for Angle3 has disappeared but the Checkbox remains. The Angle4 input has changed to "Angle Change (A2 to A4)" and now shows 45 instead of 0. Note also that in the Formulae on the Graphics screen, V1 is described as an Input of 74.

The Adjustment Angle now shows "N/A" as angles are not required to perform these computations so there are no angles to adjust. Angles A2, A3, and A4 are computed by the program and inserted into the respective Angle Inputs for future analysis. The Angles shown on the Graphics screen do not include the Angle Adjustment.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Notice the Checkbox in front of where the Angle2 input line was below the Graphics. Left click on it.

Figure 39: Vectors (EDR-Momentum) Solution - V3 Speed Input

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
 28.6886 = Abs(-25.66 / Cos(26.5646 + Abs(0)))

DV2 = DV1 * (W1 / W2)
 34.4263 = 28.6886 * (3000 / 2500)

AngleC = 180 - (A3 + PDOF1)
 138.5712 = 180 - (14.864 + 26.5646)

AngleA = A2 - A4
 45 = 45 - 0

ALPHA2 = 180 - (PDOF1 + A2)
 108.4353 = 180 - (26.5646 + 45)

PDOF1 (LM) = 26.5646

AngleB = 180 - (ALPHA2 + AngleA)
 26.5646 = 180 - (108.4353 + 45)

V1 = Proprietary Formula
74 = Proprietary Formula

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
 21.7728 = 34.4263 * Sin(26.5646) / Sin(45)

V3 = Input Variable
50.0136 = Input Variable

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
 46.1877 = 34.4263 * Sin(180 - (45 + 26.5646)) / Sin(45)

PDOF2 (LM) = -108.4353

<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	<input type="checkbox"/> V1 = 74 M/H	<input type="checkbox"/> V2 = 21.7728 M/H	<input type="checkbox"/> V3 = 50.0136 M/H	<input type="checkbox"/> V4 = 46.1877 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5333 f/s	V2 = 31.9335 f/s	V3 = 73.3532 f/s	V4 = 67.742 f/s

Lng. DeltaV (X):	M/H	-25.66
Lat. DeltaV (Y):	M/H	12.8298
PDOF1 (Degrees):		26.5646

<input type="checkbox"/> Speed V3 (M/H):		50.0136
Angle Change (A2 to A4):		45

<input checked="" type="checkbox"/> Adjustment Angle:		10
Weight (1):	lbs	3000
Weight (2):	lbs	2500

Iteration/FDA	Formulae*	N
>DLM	>LMO	>PFL
Open .VEC File	Save .VEC File	

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Clicking on that Checkbox brings up an Input for the V3 speed which should show 50.0136 M/H if that is the Primary input. A keen eye will notice that some of the Formulae have again changed along with the data. The Input block asking for Angle2 has disappeared but the Checkbox remains. The Angle4 input still shows the change to "Angle Change (A2 to A4)" and still shows 45 instead of 0. Note also that in the Formulae on the Graphics screen, V3 is described as an Input of 50.0136.

V1 may show 73.9999 (truncation) and Proprietary Formula. The specific formula is not needed as it can be proved correct using a variety of methods.

So how did we get V3 and Why? Tackling the "Why" question first, because maybe the EDR did not collect the V1 information and we were unsure of other methods of obtaining V1. If we are able to get a good post-impact speed at separation for V3, it is always a good idea to run it as a cross check. Why not bolster your own case whenever possible? As for the "How" aspect, one good way is to do a skid to stop computation if possible, but this is just one way of many that may present themselves.

The Adjustment Angle now shows "N/A" as angles are not required to perform these computations therefore there are no angles to adjust. Angles A2, A3, and A4 are computed by the program and inserted into the respective Angle Inputs for future analysis. The Angles shown on the Graphics screen do not include the Angle Adjustment.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Uncheck the V3 Checkbox.

Figure 40: Vectors (EDR-Momentum) Solution - V3 Speed Input with Adjustments

$DV1 = \text{Abs}(DV1X / \text{Cos}(PDOF1 + \text{Abs}(\text{SlipAngle})))$
 $28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.4263 = 28.6886 * (3000 / 2500)$

$\text{AngleC} = 180 - (A3 + PDOF1)$
 $138.5713 = 180 - (14.864 + 26.5646)$

$\text{AngleA} = A2 - A4$
 $45 = 55 - 10$

$\text{ALPHA2} = 180 - (PDOF1 + A2)$
 $98.4353 = 180 - (26.5646 + 55)$

PDOF1 (LM) = 26.5646

Adjustment Angle = 10

$DV1 = 28.6886 \text{ M/H}$
 $DV1 = 42.0767 \text{ f/s}$

$DV2 = 34.4263 \text{ M/H}$
 $DV2 = 50.492 \text{ f/s}$

Lng. DeltaV (X): M/H
 Lat. DeltaV (Y): M/H
 PDOF1 (Degrees):

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $36.5646 = 180 - (98.4353 + 45)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $74.0001 = 28.6886 * \text{Sin}(138.5713) / \text{Sin}(14.864)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $29.0038 = 34.4263 * \text{Sin}(36.5646) / \text{Sin}(45)$

$V3 = DV1 * \text{Sin}(PDOF1) / \text{Sin}(A3)$
 $50.0137 = 28.6886 * \text{Sin}(26.5646) / \text{Sin}(14.864)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$
 $48.1595 = 34.4263 * \text{Sin}(180 - (45 + 36.5646)) / \text{Sin}(45)$

PDOF2 (LM) = -98.4353

$DV1 = 28.6886 \text{ M/H}$
 $DV1 = 42.0767 \text{ f/s}$

$DV2 = 34.4263 \text{ M/H}$
 $DV2 = 50.492 \text{ f/s}$

$V1 = 74.0001 \text{ M/H}$
 $V1 = 108.5335 \text{ f/s}$

$V2 = 29.0038 \text{ M/H}$
 $V2 = 42.539 \text{ f/s}$

$V3 = 50.0137 \text{ M/H}$
 $V3 = 73.3534 \text{ f/s}$

$V4 = 48.1595 \text{ M/H}$
 $V4 = 70.634 \text{ f/s}$

Angle2 (Degrees):
 Angle3 (Degrees):
 Angle4 (Degrees):

Adjustment Angle:

Weight (1): lbs
 Weight (2): lbs

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

It is time to examine Adjustment Angle. Change it to Zero.

Figure 41: Vectors (EDR-Momentum) Solution - V3 Speed Input with Adjustment Angle = 0 degrees

The screenshot displays the REC-TEC Platinum software interface for calculating EDR-Momentum. The window title is "REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]". The interface includes a menu bar, a toolbar, and a main workspace with calculation formulas, a vector diagram, and a control panel.

Calculations:

$$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$$

$$28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$$

$$DV2 = DV1 * (W1 / W2)$$

$$34.4263 = 28.6886 * (3000 / 2500)$$

$$\text{AngleC} = 180 - (A3 + \text{PDOF1})$$

$$138.5713 = 180 - (14.864 + 26.5646)$$

$$\text{AngleA} = A2 - A4$$

$$45 = 45 - 0$$

$$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$$

$$108.4353 = 180 - (26.5646 + 45)$$

Results:

PDOF1 (LM) = 26.5646 **PDOF2 (LM) = -108.4353**

Adjustment Angle = 0

	A1 = 0	A2 = 45	A3 = 14.864	A4 = 0	
<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	V1 = 74.0001 M/H	V2 = 21.7728 M/H	V3 = 50.0137 M/H	V4 = 46.1877 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5335 f/s	V2 = 31.9335 f/s	V3 = 73.3534 f/s	V4 = 67.742 f/s

Diagram: A vector diagram showing a horizontal red vector pointing right. A green vector points up and right from the tip of the red vector. A blue vector points up and left from the tip of the green vector. A dashed line extends from the tip of the blue vector back to the tip of the red vector, forming a triangle. The angle between the red and blue vectors is labeled as AngleA.

Control Panel:

- Lng. DeltaV (X): M/H -25.66
- Lat. DeltaV (Y): M/H 12.8298
- PDOF1 (Degrees): 26.5646
- Angle2 (Degrees): 45
- Angle3 (Degrees): 14.8641
- Angle4 (Degrees): 0
- Adjustment Angle: 0
- Weight (1): lbs 3000
- Weight (2): lbs 2500
- Buttons: Iteration/FDA, Formulae*, N, >DLM, >LMO, >PFL, C, Open .VEC File, Save .VEC File

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Notice that the Angles on the Graphics section have changed. Look what also changed; V2 and V4. V1 and V3 have not changed.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

As long as we are examining the Adjustment Angle, make it 30.

Figure 42: Vectors (EDR-Momentum) Solution - V3 Speed Input with Adjustment Angle = 30 degrees

$DV1 = \text{Abs}(DV1X / \text{Cos}(\text{PDOF1} + \text{Abs}(\text{SlipAngle})))$
 $28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.4263 = 28.6886 * (3000 / 2500)$

$\text{AngleC} = 180 - (A3 + \text{PDOF1})$
 $138.5713 = 180 - (14.864 + 26.5646)$

$\text{AngleA} = A2 - A4$
 $45 = 75 - 30$

$\text{ALPHA2} = 180 - (\text{PDOF1} + A2)$
 $78.4353 = 180 - (26.5646 + 75)$

PDOF1 (LM) = 26.5646

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $56.5646 = 180 - (78.4353 + 45)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $74.0001 = 28.6886 * \text{Sin}(138.5713) / \text{Sin}(14.864)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $40.6291 = 34.4263 * \text{Sin}(56.5646) / \text{Sin}(45)$

$V3 = DV1 * \text{Sin}(\text{PDOF1}) / \text{Sin}(A3)$
 $50.0137 = 28.6886 * \text{Sin}(26.5646) / \text{Sin}(14.864)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA})$
 $47.6978 = 34.4263 * \text{Sin}(180 - (45 + 56.5646)) / \text{Sin}(45)$

PDOF2 (LM) = -78.4353

+Y	+X	Adjustment Angle = 30	A1 = 0	A2 = 75	A3 = 14.864	A4 = 30
<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	<input type="checkbox"/> V1 = 74.0001 M/H	<input type="checkbox"/> V2 = 40.6291 M/H	<input type="checkbox"/> V3 = 50.0137 M/H	<input type="checkbox"/> V4 = 47.6978 M/H	
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5335 f/s	V2 = 59.5893 f/s	V3 = 73.3534 f/s	V4 = 69.9569 f/s	

Lng. DeltaV (X): M/H

Lat. DeltaV (Y): M/H

PDOF1 (Degrees):

Angle2 (Degrees):

Angle3 (Degrees):

Angle4 (Degrees):

Adjustment Angle:

Weight (1): lbs

Weight (2): lbs

Iteration/FDA

Formulae*

N

>DLM

>LMO

>PFL

C

Open .VEC File

Save .VEC File

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It looks correct. Both vehicles depart of the Cone of Departure. It looks like the centers of mass have crossed.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Left click on the light blue >LMO button to send this to 360 Linear Momentum for further analysis.

Figure 43: Vector Solution transferred to 360 Linear Momentum

The screenshot displays the REC-TEC Platinum software interface with the following data:

Linear Momentum - Unit 1		Unit 2		Output - Unit 1		Output - Unit 2	
Number of Fragments	1 2 3 4	Number of Fragments	1 2 3 4	PDOF (A1):	26.5647 degrees	PDOF (A2):	-78.4352 degrees
<input type="checkbox"/> Inline Collision (EBS)	LHCS/H	V2 Speed (Known)	M/H	Impulse:	3920.1827 lbf*s	Impulse:	3920.1827 lbf*s
<input type="checkbox"/> Inline Collision (V' & Ed or Dv1)		Approach Data:		DeltaV-Lat:	12.8297 M/H	DeltaV-Lat:	-33.7274 M/H
Approach Data:		Angle (2)	degrees 75	DeltaV-Lat:	18.817 f/s	DeltaV-Lat:	-49.4669 f/s
Angle (1)	degrees 0	Departure Data:	M/A File	DeltaV-Lng:	25.6599 M/H	DeltaV-Lng:	6.9016 M/H
Departure Data:	M/A File	Even Fragments:		DeltaV-Lng:	37.6345 f/s	DeltaV-Lng:	10.1223 f/s
Odd Fragments:		Angle (4)	degrees 30	Delta V:	28.6886 M/H	Delta V:	34.4263 M/H
Angle (3)	degrees 14.864	Weight	lbs 2500	Delta V:	42.0766 f/s	Delta V:	50.4919 f/s
Weight	lbs 3000	Speed (D)	M/H 47.6978	Post Impact		Post Impact	
Speed (D)	M/H 50.0137	Enter 0 to use mu/Dist Input		Speed:	50.0137 M/H	Speed:	47.6978 M/H
	Enter X to use DeltaV Inputs			Speed:	73.3534 f/s	Speed:	69.9567 f/s
				Intercept (Pre-Impact)		Separation (Post-Impact)	
				Angle:	75 degrees	Angle:	15.136 degrees
				Momentum:	266970.7333 M/H*lbs	Momentum:	266970.7333 M/H*lbs
				Energy:	686579.4149 ft*lbf	Energy:	440637.4371 ft*lbf
				Energy:	245941.9778 ft*lbf	Energy:	253725.255 ft*lbf
				Speed:	74.6352 M/H	Speed:	13.072 M/H
				Speed:	109.465 f/s	Speed:	19.1723 f/s
				Impact		Impact	
				Speed:	74 M/H	Speed:	40.629 M/H
				Speed:	108.5334 f/s	Speed:	59.5892 f/s
				eVelocity:	.1509 - (e)	rVelocity:	.1751 - (Vs/Vc)

Buttons at the bottom of the interface:

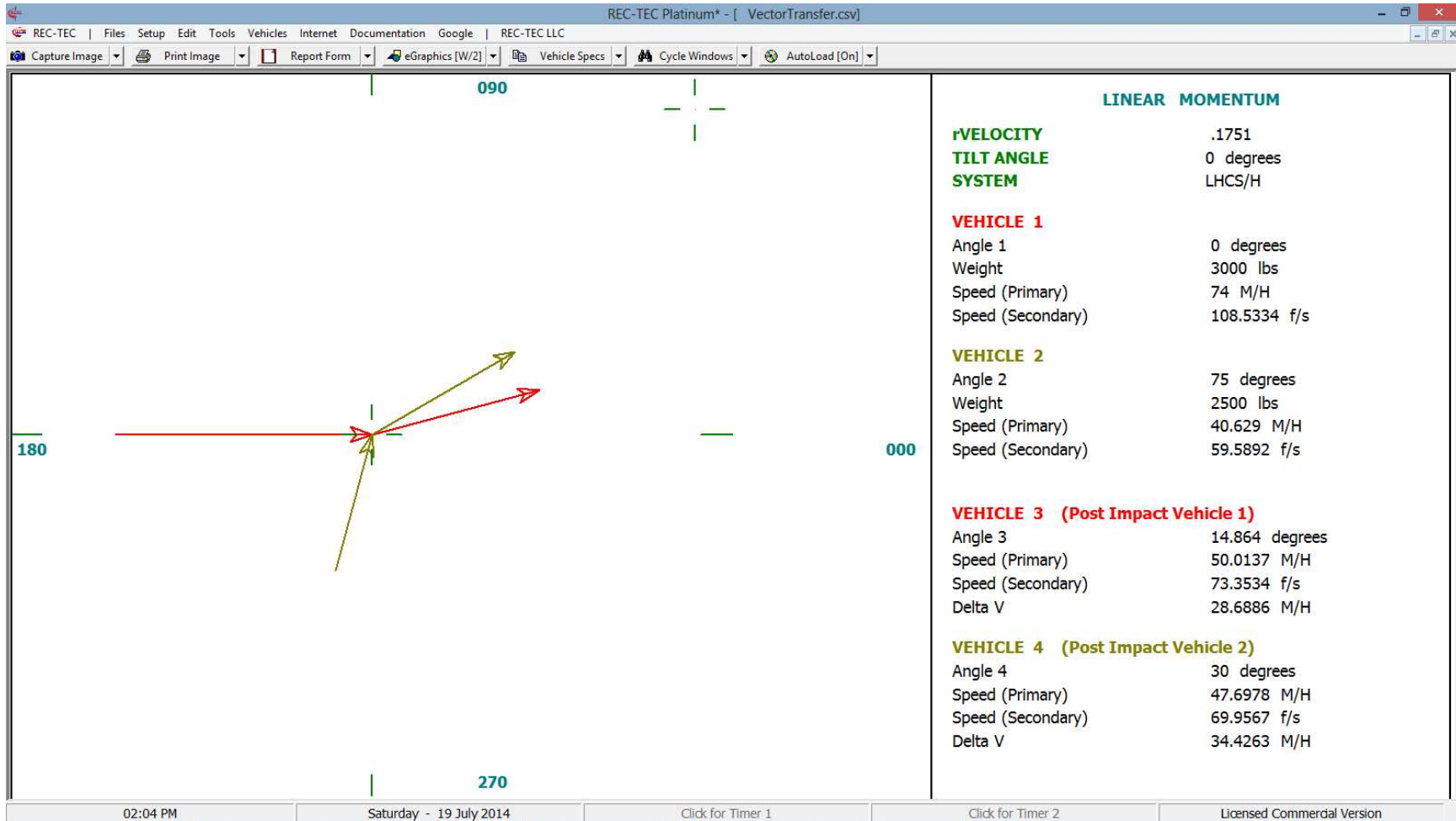
- Energy Momentum
- Vector Analysis
- Velocity Vectors
- Iteration/FDA
- Formulae
- Graphics
- Animation
- Open .CSV File
- Formulae*
- 360LM > Vectors
- 360LM > smac-RT
- Open .LMO File
- Save .LMO File

It looks like the same problem and we are getting the same answers.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 44: Vector Solution transferred to 360 Linear Momentum Graphics

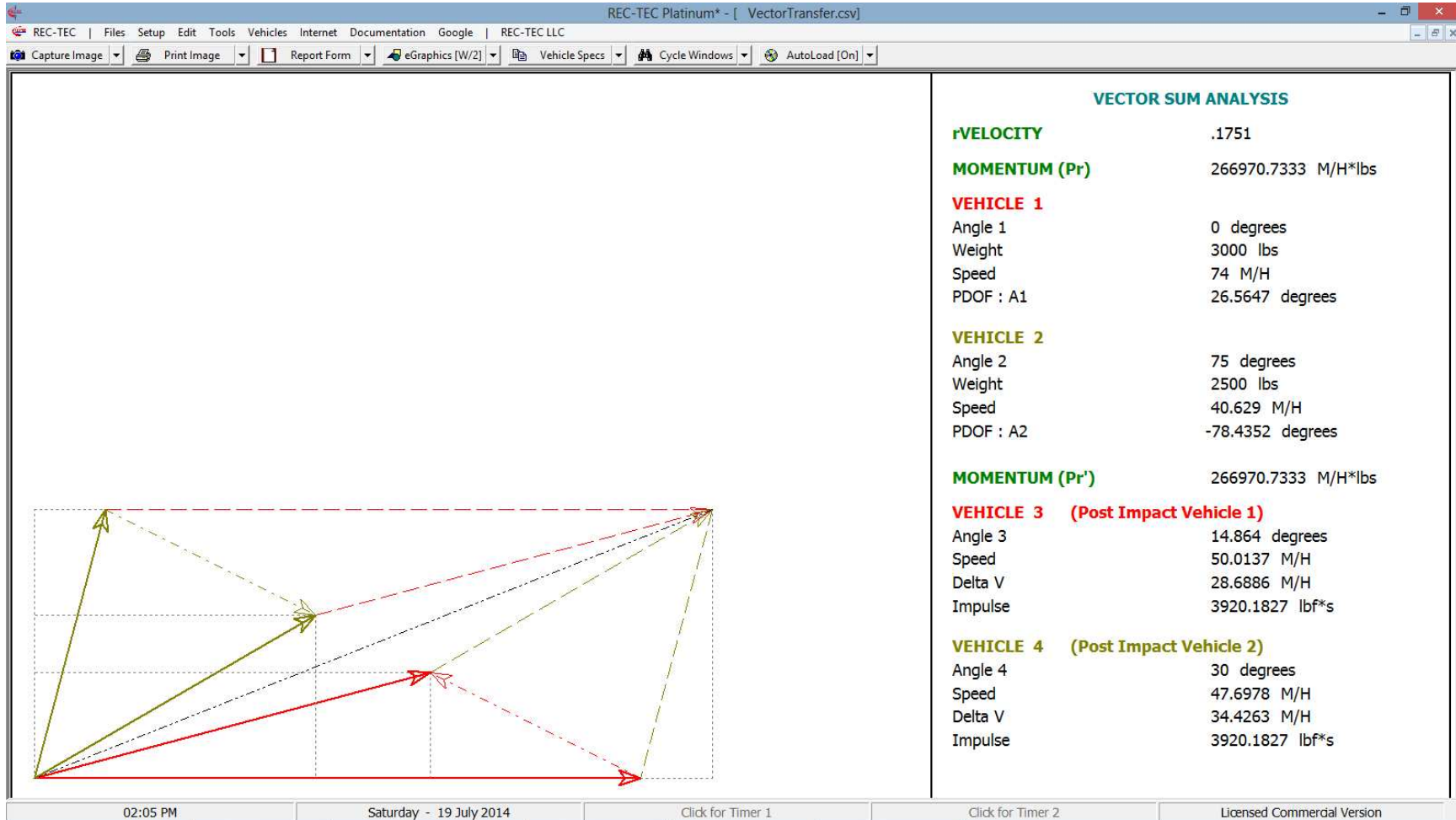


Graphics look OK. Let's examine it using Vector Sum Analysis.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 45: Vector Solution transferred to 360 Linear Momentum Vector Analysis



Everything seems to be just fine here too. Looks like we have a winner. Before getting overconfident, go back to the Vector Screen, and select the V1 Speed Checkbox.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 46: Vectors (EDR-Momentum) Solution - V1 Speed Input with Adjustment Angle = 0 degrees

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]
- [x]

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- [x]

Capture Image Print Image Report Form eGraphics [W/2] Vehicle Specs Cycle Windows AutoLoad [On]

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
28.6886 = Abs(-25.66 / Cos(26.5646 + Abs(0)))

DV2 = DV1 * (W1 / W2)
34.4263 = 28.6886 * (3000 / 2500)

AngleC = 180 - (A3 + PDOF1)
138.5712 = 180 - (14.864 + 26.5646)

AngleA = A2 - A4
45 = 45 - 0

ALPHA2 = 180 - (PDOF1 + A2)
108.4353 = 180 - (26.5646 + 45)

PDOF1 (LM) = 26.5646

AngleB = 180 - (ALPHA2 + AngleA)
26.5646 = 180 - (108.4353 + 45)

V1 = Input Variable
74 = Input Variable

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
21.7728 = 34.4263 * Sin(26.5646) / Sin(45)

V3 = Sqr(V1 ^ 2 + DV1 ^ 2 - (2 * V1 * DV1 * Cos(PDOF1)))
50.0135 = Sqr(5476 + 823.0357 - 2 * 74 * 28.6886 * Cos(26.5646))

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
46.1877 = 34.4263 * Sin(180 - (45 + 26.5646)) / Sin(45)

PDOF2 (LM) = -108.4353

+Y	+X	Adjustment Angle = N/A	A1 = 0	A2 = 45	A3 = 14.864	A4 = 0
<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	<input type="checkbox"/> V1 = 74 M/H	<input type="checkbox"/> V2 = 21.7728 M/H	<input type="checkbox"/> V3 = 50.0135 M/H	<input type="checkbox"/> V4 = 46.1877 M/H	
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5333 f/s	V2 = 31.9335 f/s	V3 = 73.3532 f/s	V4 = 67.742 f/s	

Lng. DeltaV (X):	M/H	-25.66
Lat. DeltaV (Y):	M/H	12.8298
PDOF1 (Degrees):		26.5646

<input checked="" type="checkbox"/> Speed V1 (M/H):	74
<input type="checkbox"/>	
Angle Change (A2 to A4):	45

<input checked="" type="checkbox"/> Adjustment Angle:	30
Weight (1):	lbs 3000
Weight (2):	lbs 2500

Iteration/FDA	Formulae*	N
>DLM	>LMO	>PFL
Open .VEC File	Save .VEC File	C

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The numbers are back to the original numbers for the V1 Speed Input. Transfer this to 360 Linear Momentum.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 47: Vector Solution transferred to 360 Linear Momentum

The screenshot displays the REC-TEC Platinum software interface for a Vector Transfer analysis. The window title is "REC-TEC Platinum* - [VectorTransfer.csv]". The interface is divided into several sections:

- Linear Momentum - Unit 1:**
 - Number of Fragments: 1, 2, 3, 4 (radio buttons)
 - Collision type: Inline Collision (EBS) (LHCS/H), Inline Collision (V' & Ed or Dv1)
 - Approach Data: Angle (1) = 0 degrees
 - Departure Data: M/A File
 - Odd Fragments: 0
 - Angle (3) = 14.864 degrees
 - Weight = 3000 lbs
 - Speed (D) = 50.0135 M/H
 - Instructions: Enter 0 to use mu/Dist Input, Enter X to use DeltaV Inputs
- Unit 2:**
 - Number of Fragments: 1, 2, 3, 4 (radio buttons)
 - V2 Speed (Known) = M/H
 - Approach Data: Angle (2) = 45 degrees
 - Departure Data: M/A File
 - Even Fragments: 0
 - Angle (4) = 0 degrees
 - Weight = 2500 lbs
 - Speed (D) = 46.1877 M/H
 - Instructions: Enter 0 to use mu/Dist Input
- Output - Unit 1:**
 - PDOF (A1): 26.5645 degrees
 - Impulse: 3920.1874 lbf*s
 - DeltaV-Lat: 12.8297 M/H
 - DeltaV-Lat: 18.8169 f/s
 - DeltaV-Lng: 25.66 M/H
 - DeltaV-Lng: 37.6346 f/s
 - Delta V: 28.6886 M/H
 - Delta V: 42.0766 f/s
 - Post Impact: Speed = 50.0135 M/H, 73.3531 f/s
 - Intercept (Pre-Impact): Angle = 45 degrees
 - Momentum: 263317.1959 M/H*lbs
 - Energy: 588319.0397 ft*lb
 - Energy: 159522.7762 ft*lb
 - Speed: 60.5927 M/H
 - Speed: 88.8694 f/s
 - Impact: Speed = 73.9999 M/H, 108.5332 f/s
 - eVelocity: .0521 - (e)
- Output - Unit 2:**
 - PDOF (A2): -108.4354 degrees
 - Impulse: 3920.1874 lbf*s
 - DeltaV-Lat: -32.6596 M/H
 - DeltaV-Lat: -47.9007 f/s
 - DeltaV-Lng: -10.8868 M/H
 - DeltaV-Lng: -15.9673 f/s
 - Delta V: 34.4263 M/H
 - Delta V: 50.492 f/s
 - Post Impact: Speed = 46.1877 M/H, 67.7419 f/s
 - Separation (Post-Impact): Angle = 14.864 degrees
 - Momentum: 263317.1959 M/H*lbs
 - Energy: 428796.2635 ft*lb
 - Energy: 167231.1708 ft*lb
 - Speed: 13.009 M/H
 - Speed: 19.0798 f/s
 - Impact: Speed = 21.7727 M/H, 31.9334 f/s
 - rVelocity: .2146 - (Vs/Vc)

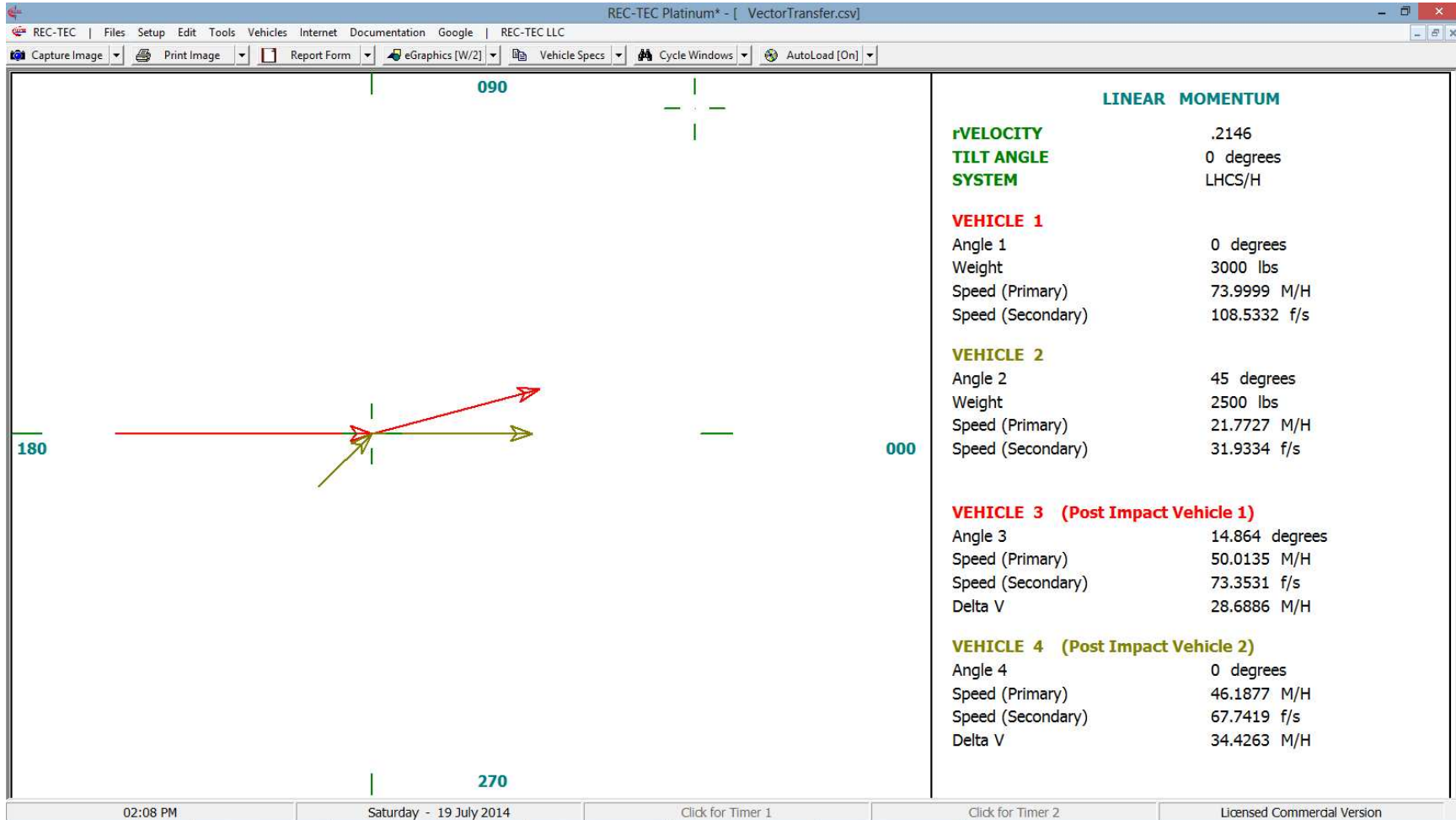
At the bottom, there is a navigation bar with buttons for Energy Momentum, Vector Analysis, Velocity Vectors, Iteration/FDA, Formulae, Graphics, Animation, Open .CSV File, Open .LMO File, and Formulae* (N). The "360LM > Vectors" button is highlighted in green.

The problem and answers appear to be the same as on the Vector screen. Go to Graphics.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 48: Vector Solution transferred to 360 Linear Momentum Graphics

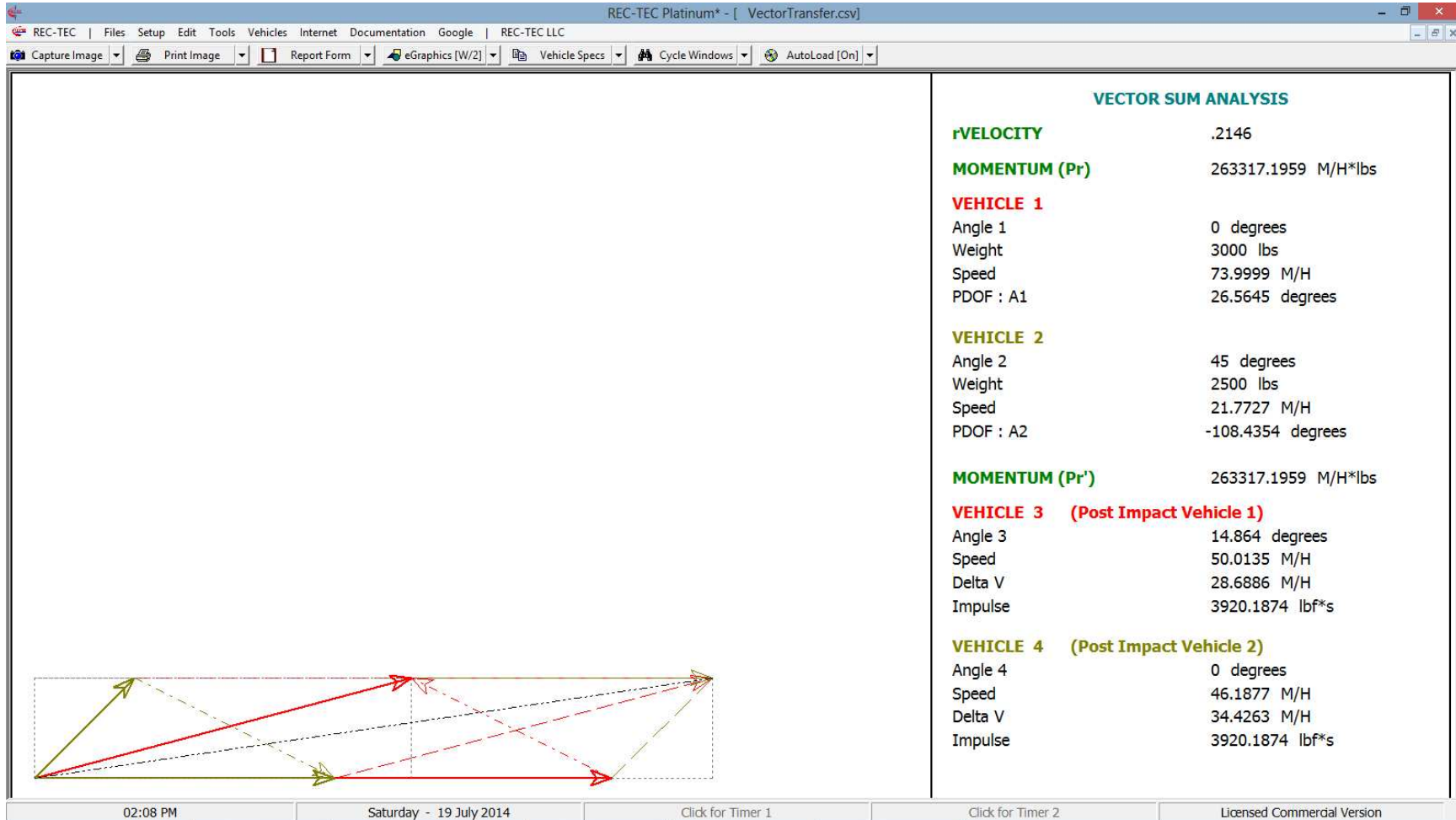


That looks OK. Now go to Vector Sum Analysis.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 49: Vector Solution transferred to 360 Linear Momentum Vector Analysis



Looks different than Figure 45, but both resultant vectors overlap each other and they meet at the same point. It must be OK.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

How can they both be OK and be so different? It is because the answers are different. Look at the V2 and V4 speeds in both problems. They are very different.

Summary:

So what is the point?

There is more than one solution that is mathematically correct, but there is only one solution that matches what actually happened. While the speed differences for Vehicle 2 at impact were minimal in these two problems, let's look at one more scenario.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Change the Adjustment Angle to 45.

Figure 50: Vectors (EDR-Momentum) Solution - V1 Speed Input with Adjustment Angle = 45 degrees

DV1 = Abs(DV1X / Cos(PDOF1 + Abs(SlipAngle)))
28.6886 = Abs(-25.66 / Cos(26.5646 + Abs(0)))

DV2 = DV1 * (W1 / W2)
34.4263 = 28.6886 * (3000 / 2500)

AngleC = 180 - (A3 + PDOF1)
138.5713 = 180 - (14.864 + 26.5646)

AngleA = A2 - A4
45 = 90 - 45

ALPHA2 = 180 - (PDOF1 + A2)
63.4353 = 180 - (26.5646 + 90)

PDOF1 (LM) = 26.5646

AngleB = 180 - (ALPHA2 + AngleA)
71.5646 = 180 - (63.4353 + 45)

V1 = DV1 * Sin(AngleC) / Sin(A3)
74.0001 = 28.6886 * Sin(138.5713) / Sin(14.864)

V2 = DV2 * Sin(AngleB) / Sin(AngleA)
46.1877 = 34.4263 * Sin(71.5646) / Sin(45)

V3 = DV1 * Sin(PDOF1) / Sin(A3)
50.0137 = 28.6886 * Sin(26.5646) / Sin(14.864)

V4 = DV2 * Sin((180 - (AngleA + AngleB)) / Sin(AngleA)
43.5464 = 34.4263 * Sin(180 - (45 + 71.5646)) / Sin(45)

PDOF2 (LM) = -63.4353

+Y					
+X	Adjustment Angle = 45	A1 = 0	A2 = 90	A3 = 14.864	A4 = 45
<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	V1 = 74.0001 M/H	V2 = 46.1877 M/H	V3 = 50.0137 M/H	V4 = 43.5464 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5335 f/s	V2 = 67.742 f/s	V3 = 73.3534 f/s	V4 = 63.8681 f/s

Lng. DeltaV (X):	M/H	<input type="text" value="-25.66"/>	<input type="checkbox"/> Angle2 (Degrees):	<input type="text" value="45"/>	<input checked="" type="checkbox"/> Adjustment Angle:	<input type="text" value="45"/>
Lat. DeltaV (Y):	M/H	<input type="text" value="12.8298"/>	<input type="checkbox"/> Angle3 (Degrees):	<input type="text" value="14.8641"/>	Weight (1):	lbs <input type="text" value="3000"/>
PDOF1 (Degrees):		<input type="text" value="26.5646"/>	Angle4 (Degrees):	<input type="text" value="0"/>	Weight (2):	lbs <input type="text" value="2500"/>

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Transfer this to 360 Linear Momentum.

Figure 51: Vector Solution transferred to 360 Linear Momentum

The screenshot displays the REC-TEC Platinum software interface for a vector solution. The window title is "REC-TEC Platinum* - [VectorTransfer.csv]". The interface is divided into several sections for Unit 1 and Unit 2, and their respective outputs.

Linear Momentum - Unit 1		Unit 2		Output - Unit 1		Output - Unit 2	
Number of Fragments	1 2 3 4	Number of Fragments	1 2 3 4	PDOF (A1):	26.5647 degrees	PDOF (A2):	-63.4352 degrees
<input type="checkbox"/> Inline Collision (EBS) LHCS/H <input type="checkbox"/> Inline Collision (V' & Ed or Dv1)		V2 Speed (Known) M/H <input type="text"/>		Impulse:	3920.1848 lbf*s	Impulse:	3920.1848 lbf*s
Approach Data:		Approach Data:		DeltaV-Lat:	12.8297 M/H	DeltaV-Lat:	-30.7919 M/H
Angle (1)	degrees <input type="text" value="0"/>	Angle (2)	degrees <input type="text" value="90"/>	DeltaV-Lat:	18.817 f/s	DeltaV-Lat:	-45.1615 f/s
Departure Data: <input type="button" value="M/A File"/>		Departure Data: <input type="button" value="M/A File"/>		DeltaV-Lng:	25.6599 M/H	DeltaV-Lng:	15.3957 M/H
Odd Fragments:		Even Fragments:		DeltaV-Lng:	37.6346 f/s	DeltaV-Lng:	22.5804 f/s
Angle (3)	degrees <input type="text" value="14.864"/>	Angle (4)	degrees <input type="text" value="45"/>	Delta V:	28.6886 M/H	Delta V:	34.4263 M/H
Weight	lbs <input type="text" value="3000"/>	Weight	lbs <input type="text" value="2500"/>	Delta V:	42.0766 f/s	Delta V:	50.4919 f/s
Speed (D)	M/H <input type="text" value="50.0137"/>	Speed (D)	M/H <input type="text" value="43.5464"/>	Post Impact		Post Impact	
Enter 0 to use mu/Dist Input		Enter 0 to use mu/Dist Input		Speed:	50.0137 M/H	Speed:	43.5464 M/H
Enter X to use DeltaV Inputs				Speed:	73.3534 f/s	Speed:	63.868 f/s
				Intercept (Pre-Impact)		Separation (Post-Impact)	
				Angle:	90 degrees	Angle:	30.136 degrees
				Momentum:	250234.3946 M/H*lbs	Momentum:	250234.3946 M/H*lbs
				Energy:	726878.2858 ft*lbf	Energy:	409006.1522 ft*lbf
				Energy:	317872.1336 ft*lbf	Energy:	346594.0759 ft*lbf
				Speed:	87.2313 M/H	Speed:	25.1112 M/H
				Speed:	127.9393 f/s	Speed:	36.8299 f/s
				Impact		Impact	
				Speed:	<input type="radio"/> 74 M/H	Speed:	<input type="radio"/> 46.1877 M/H
				Speed:	108.5334 f/s	Speed:	67.7419 f/s
				eVelocity:	.2732 - (e)	rVelocity:	.2878 - (Vs/Vc)

Energy Momentum	Formulae	Formulae*	N
Vector Analysis	Graphics	360LM > Vectors	
Velocity Vectors	Animation	360LM > smac-RT	
Iteration/FDA	Open .CSV File	Open .LMO File	Save .LMO File

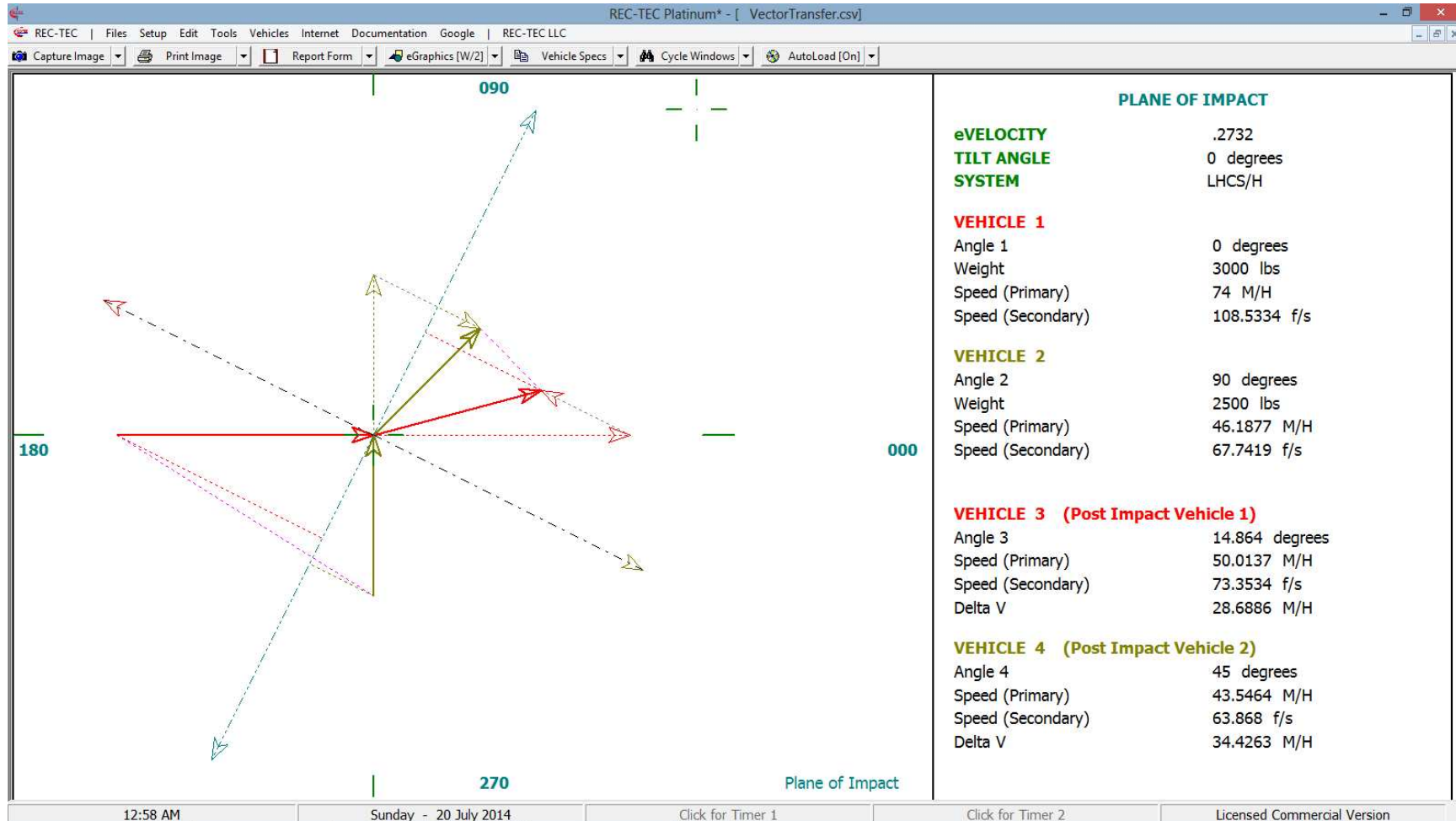
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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Now Select Graphics. Right click on the Mouse three times.

Figure 52: Vector Solution transferred to 360 Linear Momentum Graphics

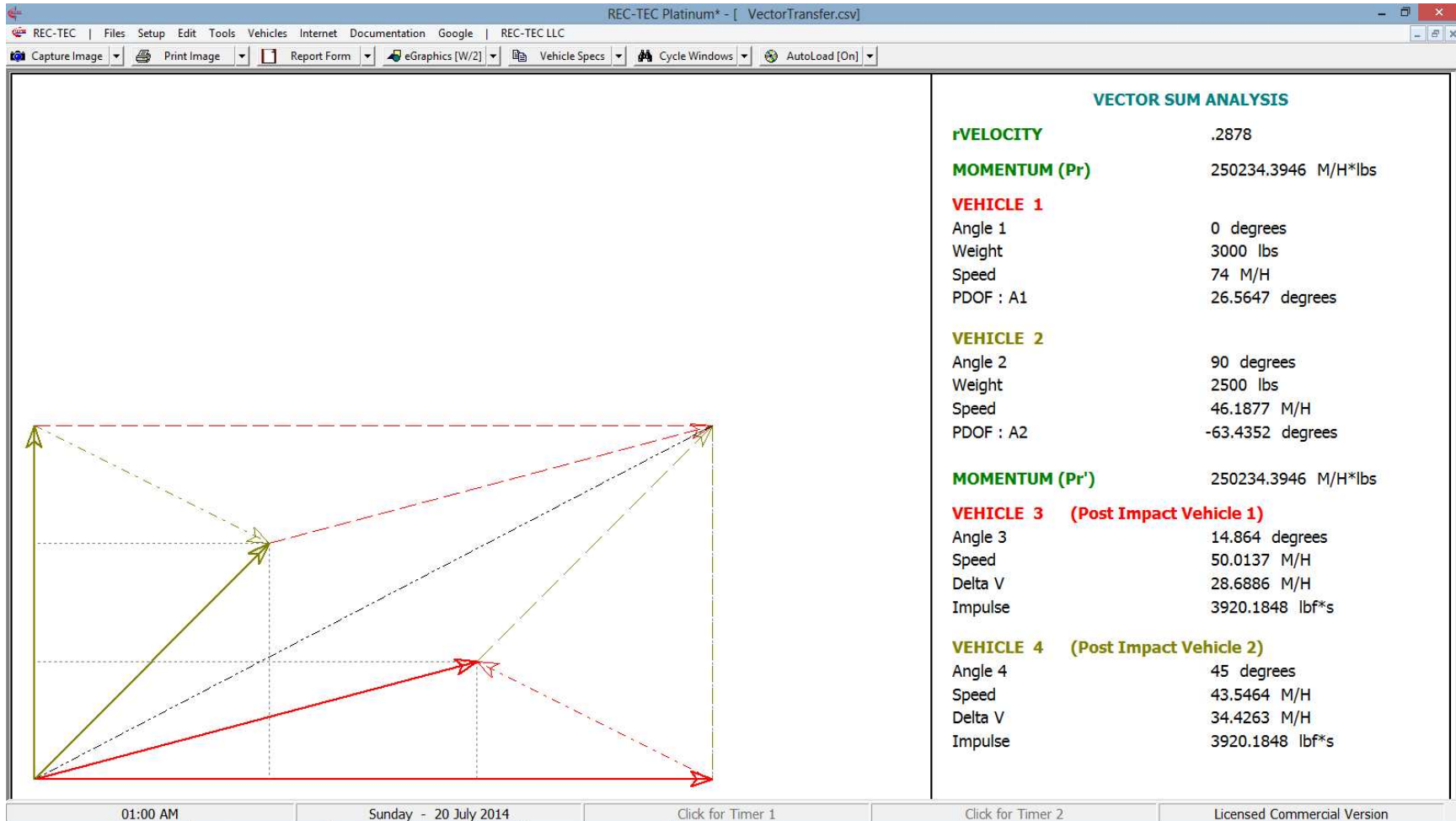


Hit the Esc Key and Select Vector Analysis.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Figure 53: Vector Solution transferred to 360 Linear Momentum Vector Analysis



The Resultant Vectors overlap and meet at a common point so it looks OK, but **V2** has gone from **21 M/H** to over **46 M/H**. That could certainly be enough to make a huge difference, both in a Civil Venue and in a Criminal one.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

That is the point!

A Final Curiosity:

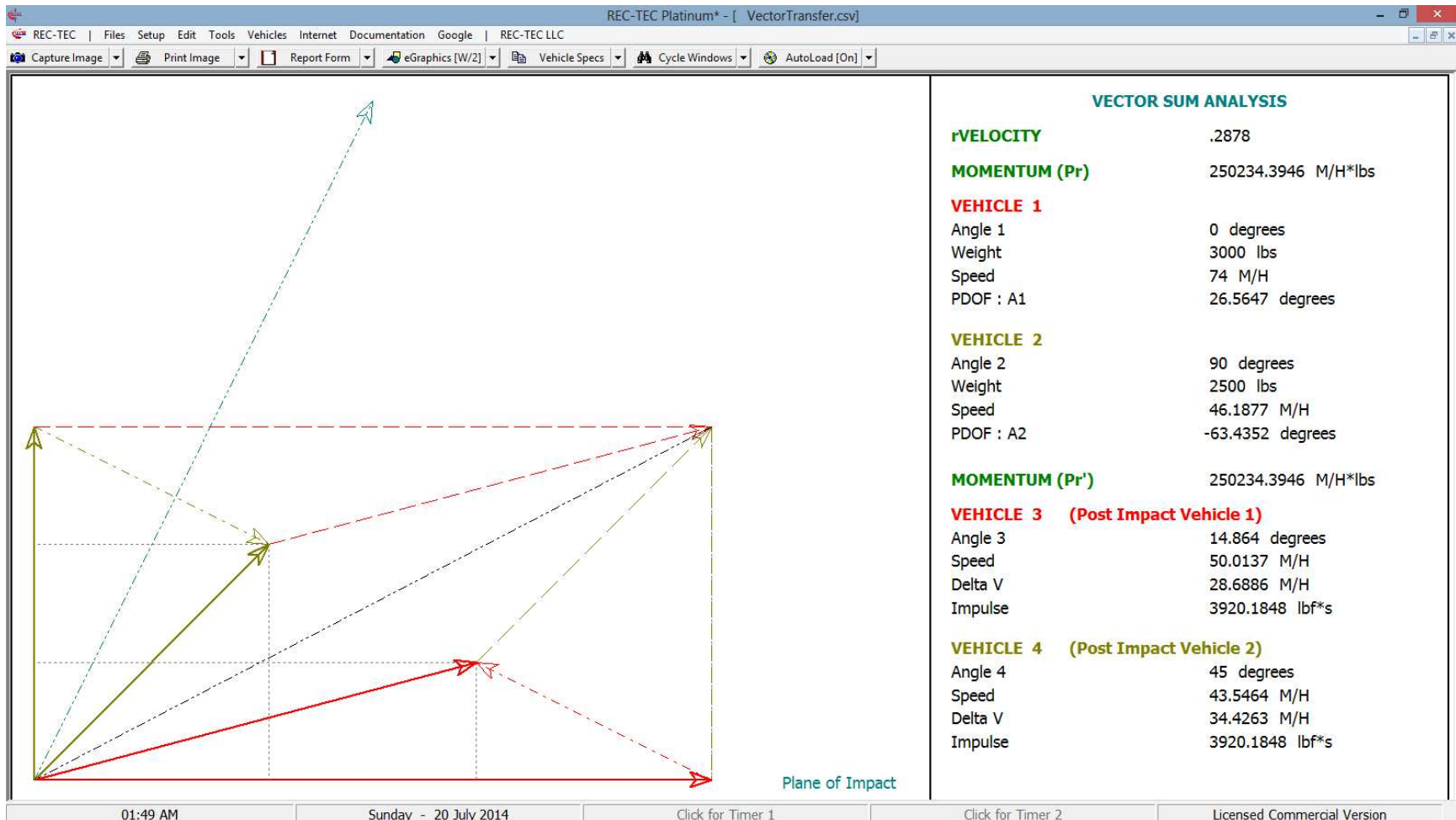
There is something about Figure 52 that is curious. Compare it to Figure 5 on page 7. The long blue line (dot-dash-dot pattern) with arrowheads at both ends passing through the collision point is the Plane of Impact. The vehicles should bounce off of that line similar to a ball bouncing off of the floor. It is almost like a mirror, reflecting beams of light off of a mirror. While not perfect analogies, there are shared qualities. Earlier it was commented that the centers of mass crossed each other, which is acceptable, and why the mirror analogy is not perfect. Still, there is something unsettling about that figure that cries out for additional scrutiny.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

The Plane of Impact can be added to the Vector Sun Analysis Graphic, and that is the ideal place to start. With Vector Analysis graphic on the screen, right click on the drawing. The Plane of Impact is now shown on the screen.

Figure 54: Vector Solution transferred to 360 Linear Momentum Vector Analysis - Plane of Impact



Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Go back to the Vector Module (Use the X in the small light colored box near the upper right of the REC-TEC Window) and change the Adjustment angle to 90 degrees.

Figure 55: Vectors (EDR-Momentum) Solution - V1 Speed Input with Adjustment Angle = 90 degrees

REC-TEC Platinum* - [Vectors (EDR-Momentum) (1)]

$DV1 = \text{Abs}(DV1X / \text{Cos}(PDOF1 + \text{Abs}(\text{SlipAngle})))$
 $28.6886 = \text{Abs}(-25.66 / \text{Cos}(26.5646 + \text{Abs}(0)))$

$DV2 = DV1 * (W1 / W2)$
 $34.4263 = 28.6886 * (3000 / 2500)$

$\text{AngleC} = 180 - (A3 + PDOF1)$
 $138.5713 = 180 - (14.864 + 26.5646)$

$\text{AngleA} = A2 - A4$
 $45 = 135 - 90$

$\text{ALPHA2} = 180 - (PDOF1 + A2)$
 $18.4353 = 180 - (26.5646 + 135)$

PDOF1 (LM) = 26.5646

$\text{AngleB} = 180 - (\text{ALPHA2} + \text{AngleA})$
 $116.5646 = 180 - (18.4353 + 45)$

$V1 = DV1 * \text{Sin}(\text{AngleC}) / \text{Sin}(A3)$
 $74.0001 = 28.6886 * \text{Sin}(138.5713) / \text{Sin}(14.864)$

$V2 = DV2 * \text{Sin}(\text{AngleB}) / \text{Sin}(\text{AngleA})$
 $43.5464 = 34.4263 * \text{Sin}(116.5646) / \text{Sin}(45)$

$V3 = DV1 * \text{Sin}(PDOF1) / \text{Sin}(A3)$
 $50.0137 = 28.6886 * \text{Sin}(26.5646) / \text{Sin}(14.864)$

$V4 = DV2 * \text{Sin}((180 - (\text{AngleA} + \text{AngleB})) / \text{Sin}(\text{AngleA}))$
 $15.3962 = 34.4263 * \text{Sin}(180 - (45 + 116.5646)) / \text{Sin}(45)$

PDOF2 (LM) = -18.4353

Adjustment Angle = 90

<input type="checkbox"/> DV1 = 28.6886 M/H	<input type="checkbox"/> DV2 = 34.4263 M/H	<input type="checkbox"/> V1 = 74.0001 M/H	<input type="checkbox"/> V2 = 43.5464 M/H	<input type="checkbox"/> V3 = 50.0137 M/H	<input type="checkbox"/> V4 = 15.3962 M/H
DV1 = 42.0767 f/s	DV2 = 50.492 f/s	V1 = 108.5335 f/s	V2 = 63.8681 f/s	V3 = 73.3534 f/s	V4 = 22.5811 f/s

Lng. DeltaV (X): M/H <input type="text" value="-25.66"/>	<input type="checkbox"/> Angle2 (Degrees): <input type="text" value="45"/>	<input checked="" type="checkbox"/> Adjustment Angle: <input type="text" value="90"/>	<input type="button" value="Iteration/FDA"/>	<input type="button" value="Formulae*"/>	<input type="button" value="N"/>
Lat. DeltaV (Y): M/H <input type="text" value="12.8298"/>	<input type="checkbox"/> Angle3 (Degrees): <input type="text" value="14.8641"/>	Weight (1): lbs <input type="text" value="3000"/>	<input type="button" value=">DLM"/>	<input type="button" value=">LMO"/>	<input type="button" value=">PFL"/>
PDOF1 (Degrees): <input type="text" value="26.5646"/>	Angle4 (Degrees): <input type="text" value="0"/>	Weight (2): lbs <input type="text" value="2500"/>	<input type="button" value="Open .VEC File"/>	<input type="button" value="Save .VEC File"/>	<input type="button" value="C"/>

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Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Transfer this data to Linear Momentum using the light blue >LMO button.

Figure 56: Vector Solution transferred to 360 Linear Momentum

The screenshot displays the REC-TEC Platinum software interface for Vector Transfer. The window title is 'REC-TEC Platinum* - [VectorTransfer.csv]'. The interface is divided into several sections:

- Linear Momentum - Unit 1:** Includes 'Number of Fragments' (1-4), 'Approach Data' (Angle 1: 0 degrees), 'Departure Data' (M/A File), 'Odd Fragments' (Angle 3: 14.864 degrees, Weight: 3000 lbs, Speed (D): 50.0137 M/H), and instructions: 'Enter 0 to use mu/Dist Input' and 'Enter X to use DeltaV Inputs'.
- Unit 2:** Includes 'Number of Fragments' (1-4), 'Approach Data' (Angle 2: 135 degrees), 'Departure Data' (M/A File), 'Even Fragments' (Angle 4: 90 degrees, Weight: 2500 lbs, Speed (D): 15.3962 M/H), and instructions: 'Enter 0 to use mu/Dist Input'.
- Output - Unit 1:** Lists parameters: PDOF (A1): 26.5647 degrees, Impulse: 3920.1843 lbf*s, DeltaV-Lat: 12.8297 M/H, 18.817 f/s, DeltaV-Lng: 25.6599 M/H, 37.6346 f/s, Delta V: 28.6886 M/H, 42.0766 f/s. Post Impact: Speed: 50.0137 M/H, 73.3534 f/s. Intercept (Pre-Impact): Angle: 135 degrees, Momentum: 164185.264 M/H*lbs, Energy: 707086.0306 ft*lbf, 436636.6509 ft*lbf, Speed: 109.2223 M/H, 160.1927 f/s. Impact: Speed: 74 M/H, 108.5334 f/s, eVelocity: .4128 - (e).
- Output - Unit 2:** Lists parameters: PDOF (A2): -18.4352 degrees, Impulse: 3920.1843 lbf*s, DeltaV-Lat: -10.8867 M/H, -15.9672 f/s, DeltaV-Lng: 32.6596 M/H, 47.9007 f/s, Delta V: 34.4263 M/H, 50.4919 f/s. Post Impact: Speed: 15.3962 M/H, 22.581 f/s. Separation (Post-Impact): Angle: 75.136 degrees, Momentum: 164185.264 M/H*lbs, Energy: 270449.3796 ft*lbf, 543373.23 ft*lbf, Speed: 48.4081 M/H, 70.9986 f/s. Impact: Speed: 43.5463 M/H, 63.868 f/s, rVelocity: .4432 - (Vs/Vc).

At the bottom, a control panel contains buttons: 'Energy Momentum', 'Formulae', 'Formulae*' (with 'N' indicator), 'Vector Analysis', 'Graphics', '360LM > Vectors', 'Velocity Vectors', 'Animation', '360LM > smac-RT', 'Iteration/FDA', 'Open .CSV File', 'Open .LMO File', and 'Save .LMO File'. The status bar shows '02:03 AM', 'Sunday - 20 July 2014', 'Click for Timer 1', 'Click for Timer 2', and 'Licensed Commercial Version'.

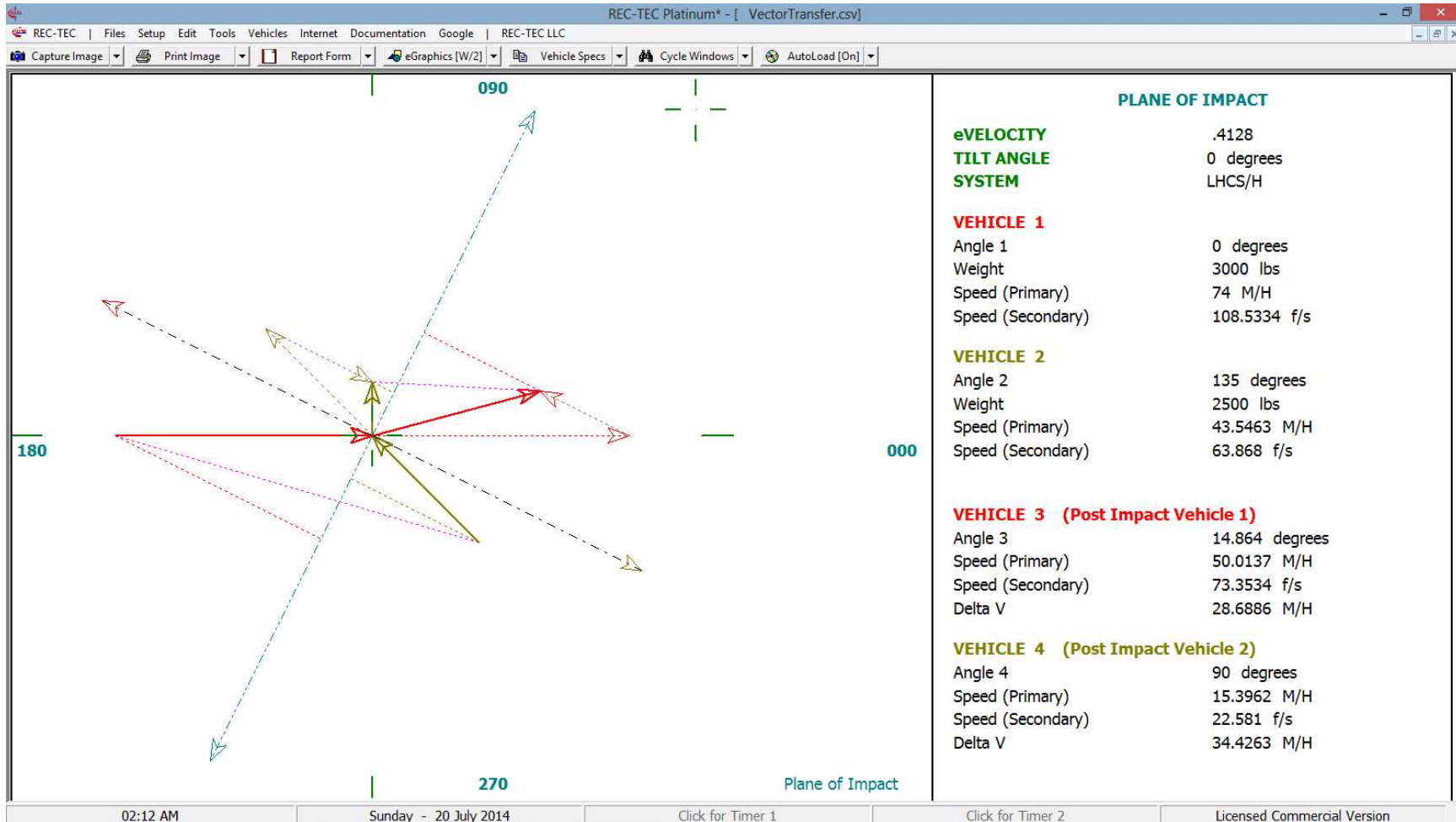
Nothing Remarkable. A2 is 135 degrees and V2 has actually dropped to 43.5 M/H.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Select Graphics and Right Click on the graphics 3 times.

Figure 57: Vector Solution transferred to 360 Linear Momentum Graphics - Plane of Impact



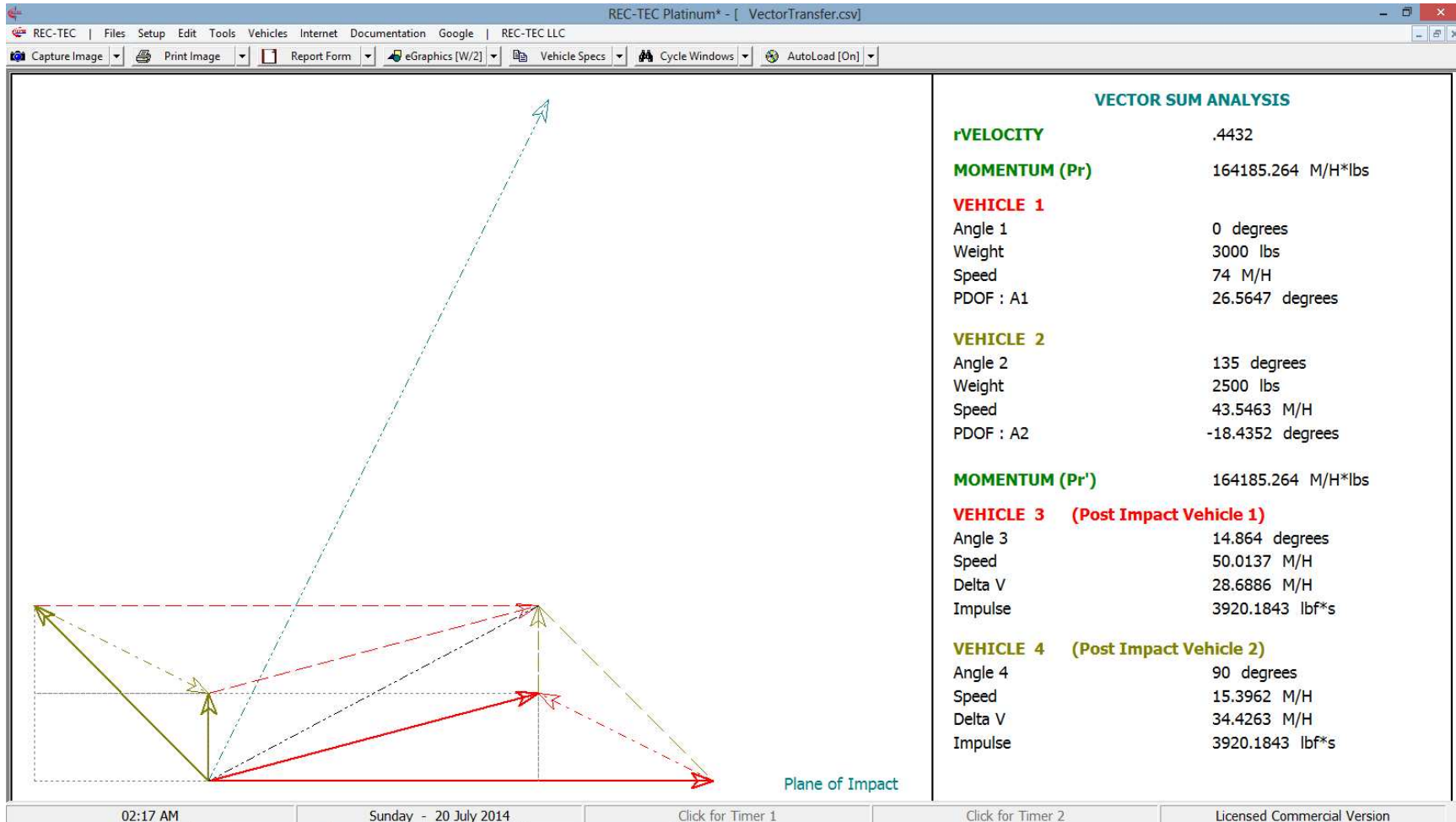
The Plane of Impact is now between the post impact Vectors.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Return to the LM interface screen (Press Esc) and Select Vector Analysis. Right Click on the graphics.

Figure 58: Vector Solution transferred to 360 Linear Momentum Vector Analysis - Plane of Impact



Same results shown here, the Plane of Impact is between the departure vectors.

Vectors (EDR-Momentum): Triangulating Momentum

Angular Collision Alternative to V3 & V4 Requirement of Linear Momentum

Conclusion:

What implications does this Plane of Impact curiosity have? Curiosity, yes, but does it rise beyond that level? Are there serious ramifications? What, if anything, does it imply?

That is a very interesting question.

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