

Autoliv Simplified Retractor Model – VPS – v1-beta

**Model update of the simplified retractor model available in
the far-side load case from 2020-02-11 in accordance with
latest LS-Dyna model**

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Model update in accordance with latest LS-Dyna model

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Model update in accordance with latest LS-Dyna model

Preamble

- The version of this release is a beta version v1-beta
 - Compared to the LS-Dyna model this beta version has a very good correlation in 23 out of 25 test loadcases, see also slides 17 and following
 - There is only an issue if the Pre-Pretensioner should be activated at a time $> 0\text{ms}$
 - The parameter `R1PPTTF` in this beta model is removed and the value in the sensor is set to 0ms to avoid possible issues

Model update in accordance with latest LS-Dyna model

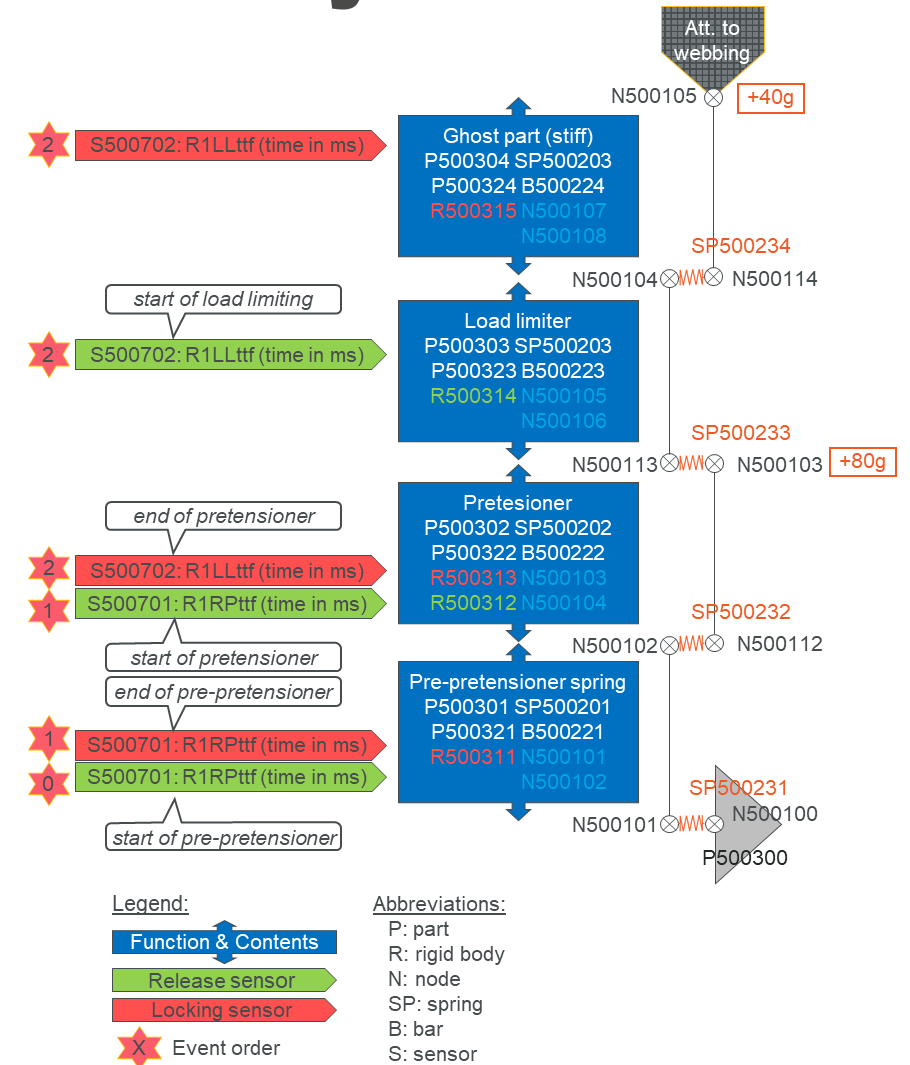
Background

- The existing “Simplified Retractor Model” without encryption, provided in the [public far-side load case](#) (2020-02-11) should be updated in accordance with the updates for the LS-Dyna model provided by Autoliv with some more features such as
 - Pre-pretensioner
 - Two pretensioner force levels
 - Two-level load limiter
 - Retractor payout stop directly after pretension
 - Retractor payout stop after a period of load limiting
- The new “Autoliv Simplified Retractor Model” should also be able to be sent to third parties without encryption

Model update in accordance with latest LS-Dyna model

Functional retractor model description

- Basics
 - Units: mm-ms-kg
- The simplified retractor model is built up of four groups of springs, bars, rigid bodies and sensors, as to the right
 - These groups existed already in Simplified Retractor Model, for public far-side load case 2020-02-11 which is available for LS-Dyna and VPS



Model update in accordance with latest LS-Dyna model

Functional retractor model description

- Spring element - Pre-Pretensioning
 - Low amount of preload defined for the spring element to generate some pay-in prior to the retractor locking or TTF
 - The amount of preload can be adjusted by parameter **R1PPfo**
 - In tension, pay-out can be generated prior to locking of the retractor (or TTF)
 - The element gets locked, if the retractor locking time is reached (**R1Rttf**) in non-pretensioning load cases or if the pretensioner is released in pretensioning load cases
- Spring element - Stroke element - Pretensioner
 - Pretensioner modelled as preloaded spring which generates pay-in once it is released
 - Y-Axis values (Force) can be scaled by parameter **R1RPpow**, to modify the force of the pretensioner
 - Time to fire (TTF) is defined by the parameter **R1Rttf**. The stroke element is first released after a short delay (**R1Rttf** + 3ms)
 - The duration of the pretensioning phase is 12ms. If it's time is reached, the pretensioning ends and the stroke element gets locked

Model update in accordance with latest LS-Dyna model

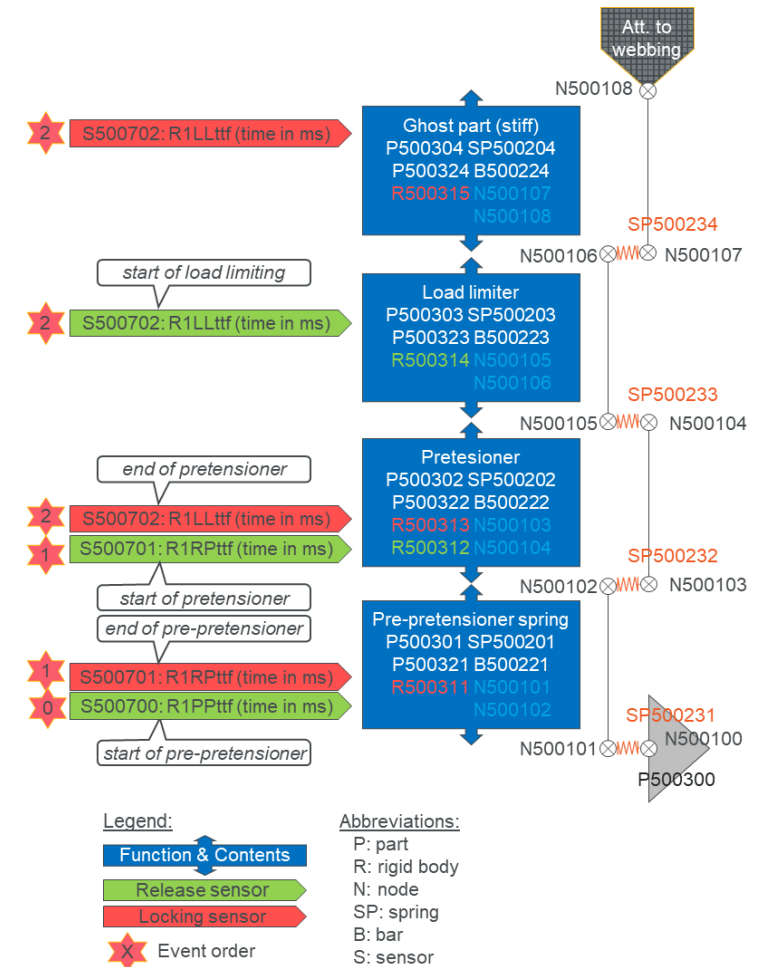
Functional retractor model description

- Spring element - Load limiter
 - The stiffness characteristics defines the resistance in the load limiting phase
 - This element is released if the retractor gets locked by **R1Rttf** in non-pretensioning load cases or if the stroke gets locked by parameter **R1Rttf+15ms** in pretensioning cases
 - The load limiting levels can be adjusted
 - The payout distance before reaching the second load level can be adjusted with **R1LL1d**
- Spring element - Ghost element – Element reserved for later modifications
 - This element is defined with a very stiff characteristic for tension and compression area, so that this element does not affect the behavior of the retractor model.
 - It can be considered as a reserve element for the case, that an additional element is required in a later stage of this project

Model update in accordance with latest LS-Dyna model

Model updates / added functionalities to far-side version of the simplified retractor model

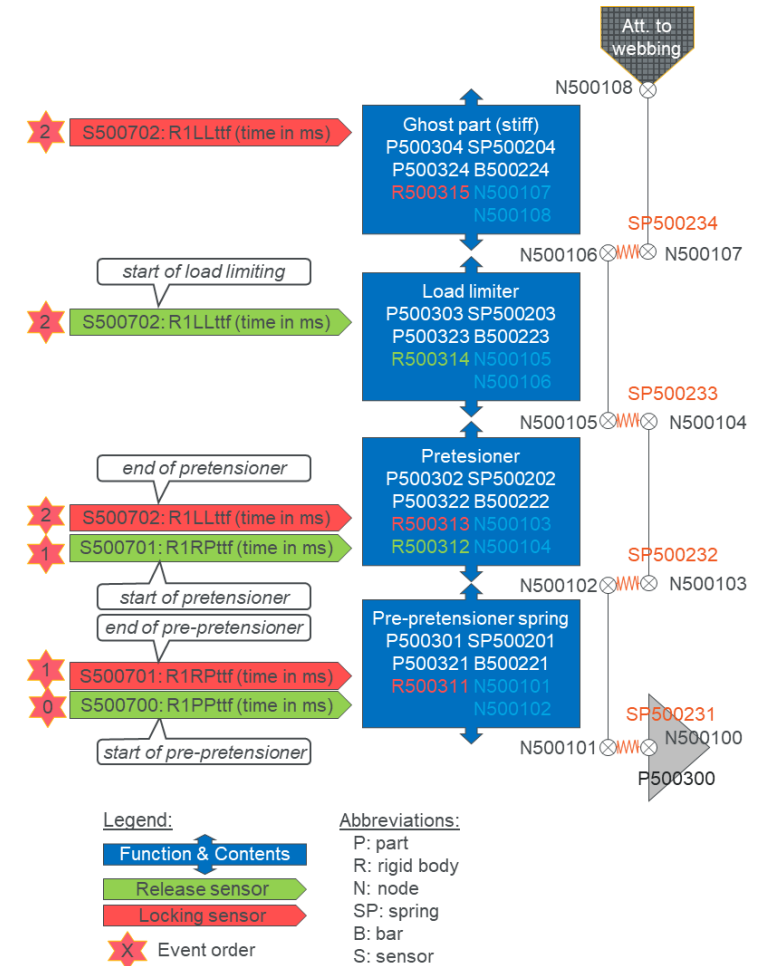
- Added RBODY and sensors (to model pre-pretensioner):
 - RBODY 500310 ret_spring_unlock_constraint (is released when pre-pretensioner starts in order to get a force acting on the pre-pretensioner spring)
 - SENSOR 500700 (sensor to know when to release the pre-pretensioner) -> currently limited in VPS-beta model to trigger at 0ms due to needed improvements for correct behavior of unloading of material used in pre-pretensioner which is released by this sensor, see also the [comparison to ls-dyna](#) on a later slide



Model update in accordance with latest LS-Dyna model

Model updates / added functionalities to far-side version of the simplified retractor model

- Added masses
 - 80 g mass between pretensioner spring and load limiter spring (N500113)
 - 40 g mass on top of spring chain, just below the webbing (N500105)
- Characteristic curves
 - Updated curves for new parameters and functionalities (see also next slide)



Model update in accordance with latest LS-Dyna model

Model updates / added functionalities to far-side version of the simplified retractor model

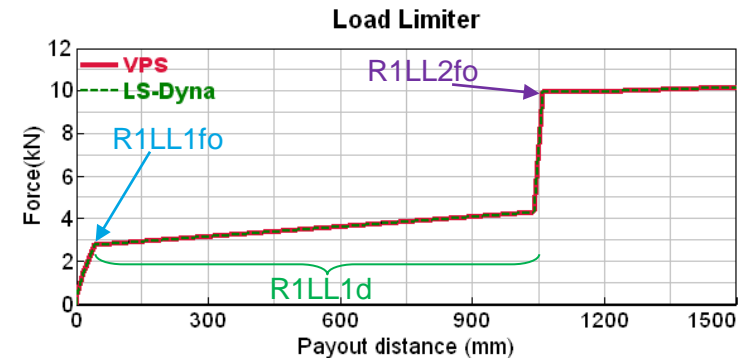
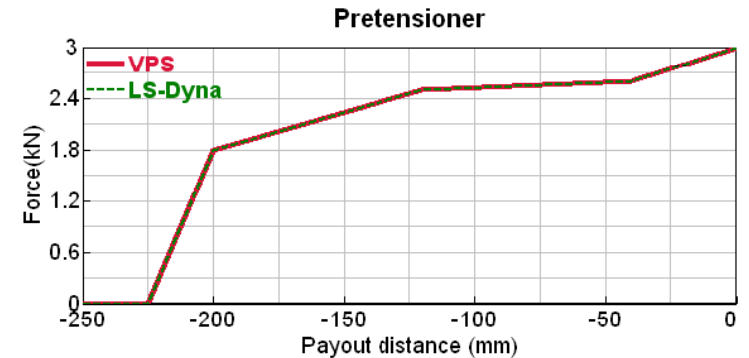
- Pre-pretensioner
 - Force level (**R1PPfo**) and start time (**R1PPttf**) can be defined by the user, and the pre-pretensioner force is turned off when the retractor time-to-fire (**R1Rttf**) occurs (**start time R1PPttf deactivated in VPS beta model, only 0ms allowed**)
- Two pretensioner force levels
 - The power of the pretensioner can be scaled (**R1RPpow**)
 - For runs without pretensioner the pretensioner power scale factor is omitted, and a selection flag marks that there should not be any pretensioner (**R1RPon**).
- Two-level load limiter
 - First load level (**R1LL1fo**), second load level (**R1LL2fo**), and the payout distance (**R1LL1d**) when the switch should happen can be defined. A short distance for film spool slack is included in the load limiter as well.
- Retractor payout stops directly after pretension, or after a period of load limiting.
 - Very high load on first or second load limiter levels (**R1LL1fo** or **R1LL2fo**) stops the payout.

Model update in accordance with latest LS-Dyna model

User defined parameters

- The following parameters should be defined by the user:

- **R1Rttf** Retractor time-to-fire in ms
- **R1RPon** Pretensioner flag: 1 if fire, 0 if no fire
- **R1RPpow** Pretensioner power: weaker ~0.8, normal ~1.0
- **R1LL1fo** Initial force in kN on first load limiter level (set to 50.0 kN for stop/stiff)
- **R1LL1d** Payout distance in mm on first load limiter level (must be <1250 mm)
- **R1LL2fo** Initial force in kN on second load limiter level (set to 50.0 kN for stop/stiff)
- **R1LLup** Load limiter function switch flag:
1 if LL1 < LL2, 0 if LL1 > LL2
- **R1PPttf** Pre-pretensioner time-to-fire in ms (restricted in VPS beta model to 0ms)
- **R1PPfo** Pre-pretensioner force in kN



Model update in accordance with latest LS-Dyna model

Limitations

- Excerpt from Autoliv simplified retractor model report:
 - Autoliv Simplified Retractor model limitations:
 - Influence of different WOS on load levels and filmspool are not included.
 - Advanced filmspool effects are not included
 - The load limiter switch is defined by a payout distance although one of the ordinary retractor models switches on time
 - Real load limiters have different progressivity; the simplified model use one pre-defined progressivity
 - Autoliv's physical load limiters are not pre-defined in the simplified retractor model
- Comparison LS-Dyna and VPS model
 - LS-Dyna model
 - With `R1PPTTF` a pre-pretensioner time-to-fire greater than 0ms can be defined
 - VPS beta model
 - The parameter `R1PPTTF` for the time-to-fire of the pre-pretensioner is set to 0ms because the unloading behavior of the pre-pretensioner spring material triggered by this parameter needs to be improved for correct behavior compared to the LS-Dyna model
 - > see also the [comparison to ls-dyna](#) on a later slide

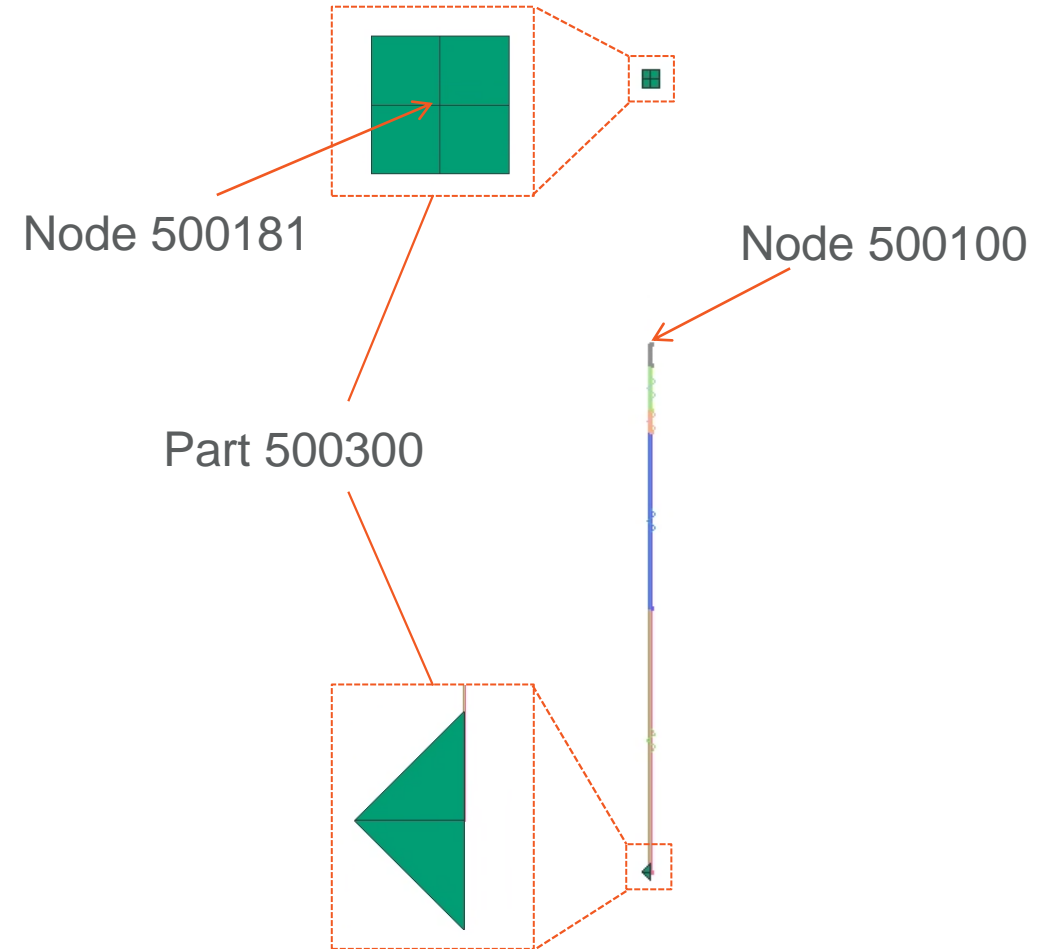
Model update in accordance with latest LS-Dyna model

Model integration

- Connection Functional model – Environment
 - The attachment of the functional model to the environment (e.g. sled), can be realized by using following card (which is already available in the pc file):

```
TIED / 500295 500395
NAME Attachment
      PART 500300
      END
      PART 1300000
      END
```

- Connection Functional model – Webbing
 - The upper patch of part 500300 should be placed at the physical retractor location – check remaining distance to enable retractor payout
 - Please use node 500100 to connect the webbing to the functional model
 - A friction-free slinging can be placed at node 500181

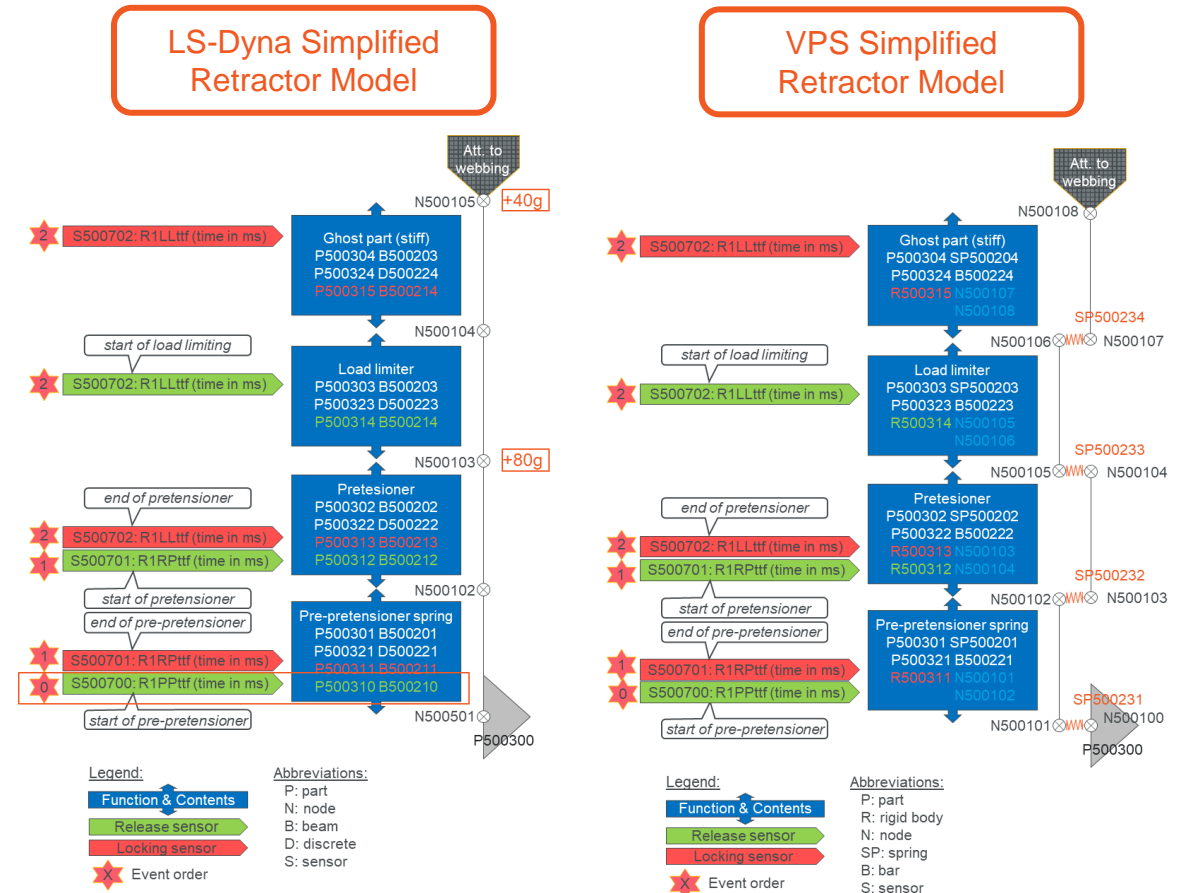


Model update in accordance with latest LS-Dyna model

Differences in the modelling compared to LS-Dyna

- Updated modelling in VPS
 - Difference in availability of functions in both codes
 - Added springs which is ok, since deformable part is very stiff
 - Switchable rigid body definitions are used as substitute for activation/deactivation of deformable parts (PART_SENSOR in LS-Dyna)
 - Mass update compared to Version from 2020-02-11 for better correlation to LS-Dyna
 - Masses have been reduced by 90% for
 - Added springs 500231-500234
 - Load limiter spring 500203
 - Ghost element spring 500204

Direct comparison of masses not possible due to different modelling approaches



Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model

- Matrix of validation loadcases
 - 25 runs to be compared with the results of LS-Dyna
 - The parameter settings for each verification run are found in the table below:

		X												X				X				X		Y		Y	
Run no.	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Retractor Settings	Retractor ttf (ms)	R1Rttf	10	10	10	10	10	10	10	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	1010	1010	
	Pretensioner on/off	R1RPon	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	1	1	
	RP power	R1RPpow	0.8	1	1	0.8	1	1	1	1	1	1	1	1	1	1	1	0.95	0.95	0.95	1	1	1	1	1	1	
	LL1 force (kN)	R1LL1fo	2.2	2.2	2.8	3.64	3.64	3.64	4.5	3.1	3.6	6.5	6.5	3.2	3.2	4.6	4.6	4.55	3.3	4.2	3.3	50	50	50	3.2	3.2	3.95
	LL2 force (kN)	R1LL2fo	10	10	10	10	10	10	10	10	10	10	10	1.3	1.3	1.9	1.9	1.9	8.1	6.5	50	10	10	10	1.3	1.3	1.55
	LL1<LL2?	R1LLup	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
	LL1 -> LL2 (mm)	R1LL1d	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	70	261	60	260	292	173	153	173	1000	1000	1000	261	261	261	
	Pre-pret. f (kN)	R1PPfo	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.5	0.5	
	Pre-pret. ttf (ms)	R1PPttf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	
Applied Force	F: pre-force level	R LOADL	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.48	0.48	
	F: LL1 force level	R LOADH1	2.6	2.6	3.3	4.1	4.1	4.1	4.9	3.45	4.1	6.9	6.9	3.6	3.6	5	5	5	3.7	4.6	3.7	6.9	10	10	3.6	3.6	4.35
	F: LL2 force level	R LOADH2	2.6	2.6	3.3	4.1	4.1	4.1	4.9	3.45	4.1	6.9	4.1	1.5	1.5	2.1	2.1	2.1	8.5	7	8.5	6.9	4.1	4.1	1.5	1.5	1.75
	F: ramp up start time	R LOADTS	1	1	5	5	5	5	5	5	15	5	5	5	5	5	5	5	5	5	5	5	5	1005	1005	1005	
	F: ramp up end time	R LOADTP	31	31	35	35	35	35	35	35	45	45	35	35	35	35	35	35	35	35	35	45	35	35	1035	1035	1035
	F: plateau end time	R LOADTM	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	40	61	40	60	60	44	43	44	1200	1200	1200	1061	1061	1061

x = Pretensioner deactivated / only load limiter

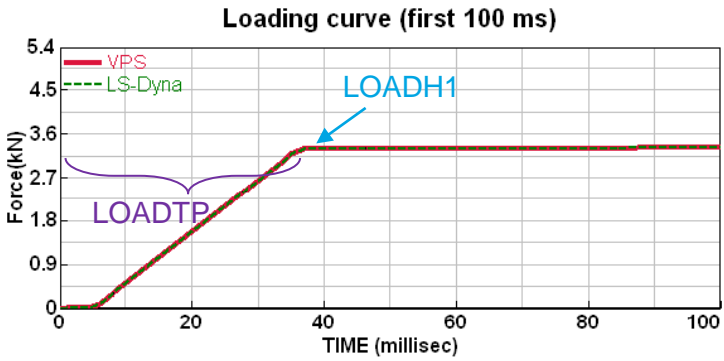
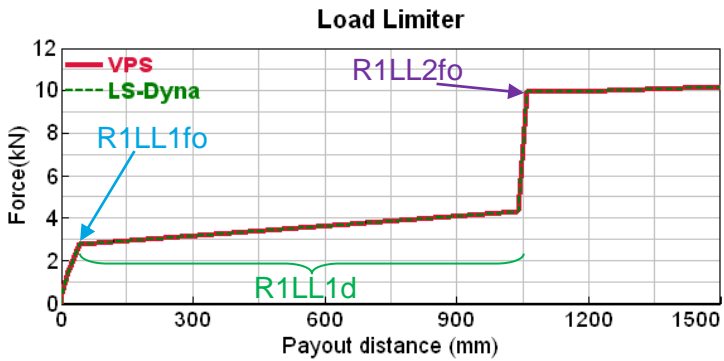
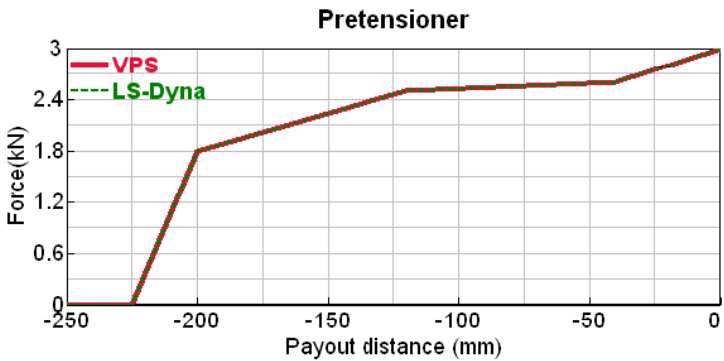
y = Pre-Pretensioner at time > 0ms

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model

- Example of parameter set for loading and retractor
 - Autoliv generic belt retractor
 - Loadcase setup 03

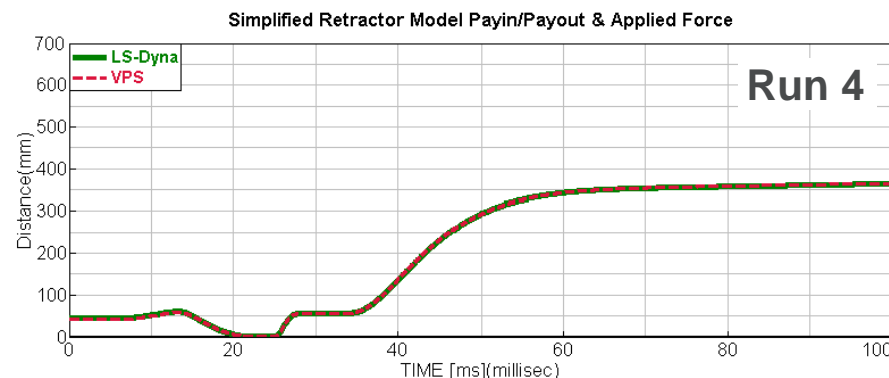
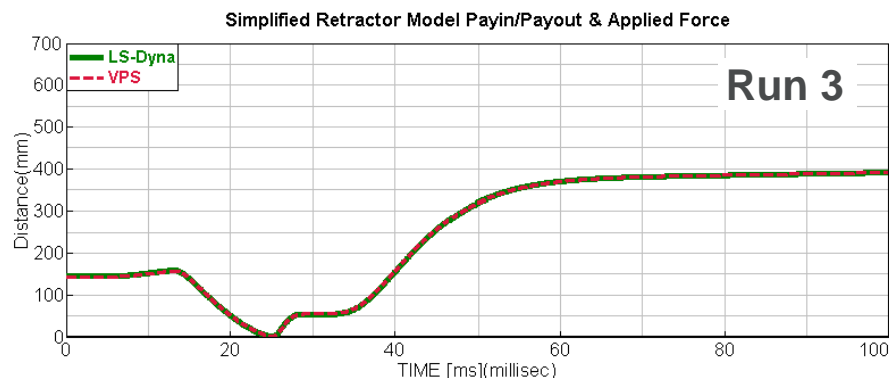
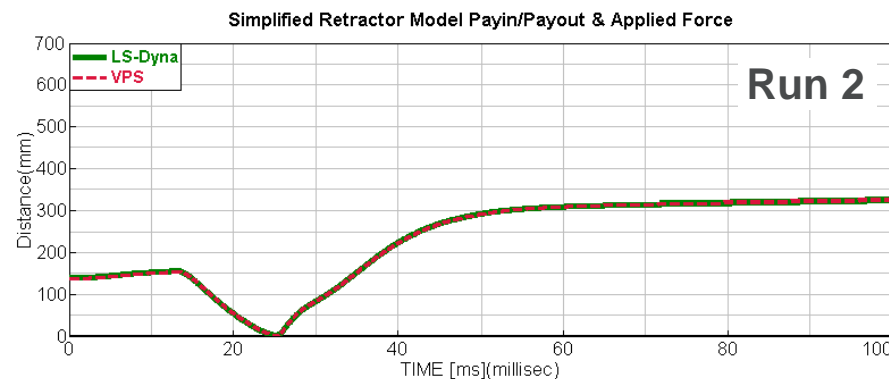
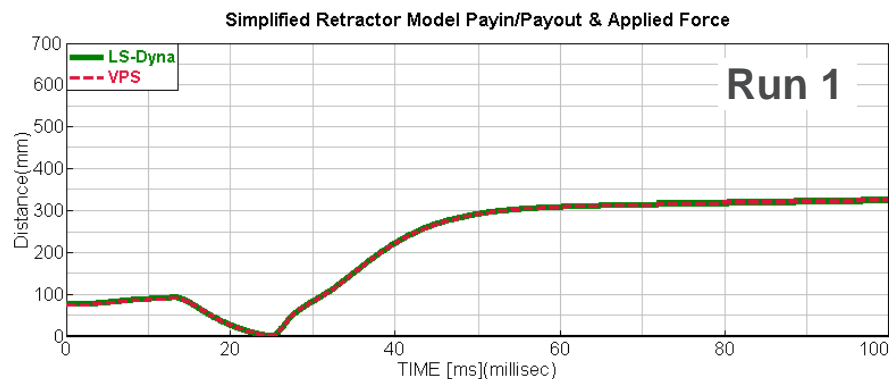
Retractor Settings	Run no.	Name	3	
	Retractor ttf (ms)	R1Rttf	10	} Pretensioner is activated at 13ms until 25ms
	Pretensioner on/off	R1RPon	1	
	RP power	R1RPpow	1	Pretensioner power scale factor: weaker ~0.8, normal ~1.0
	LL1 force (kN)	R1LL1fo	2.8	Initial force 2.8kN on first load limiter level
	LL2 force (kN)	R1LL2fo	10	Initial force 10kN on second load limiter level
	LL1<LL2?	R1LLup	0	Load limiter = 0 (0 for LL1>LL2, 1 for LL1<LL2)
	LL1 -> LL2 (mm)	R1LL1d	1000	Payout distance 1000mm on first load limiter level
	Pre-pret. f (kN)	R1PPfo	0.02	} Pre-Pretension force of 0.02kN from time 0ms
	Pre-pret. ttf (ms)	R1PPttf	0	
Applied Force	F: pre-force level	R LOADL	0.02	Pre-force level of 0.02kN until ramp up start time
	F: LL1 force level	R LOADH1	3.3	First force level 3.3kN
	F: LL2 force level	R LOADH2	3.3	
	F: ramp up start time	R LOADTS	5	
	F: ramp up end time	R LOADTP	35	Ramp up end time 35+2= 37ms
	F: plateau end time	R LOADTM	1200	



Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 1 to 4

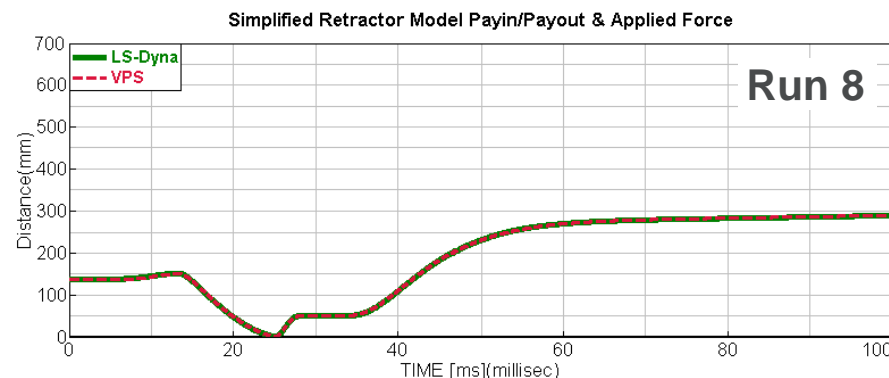
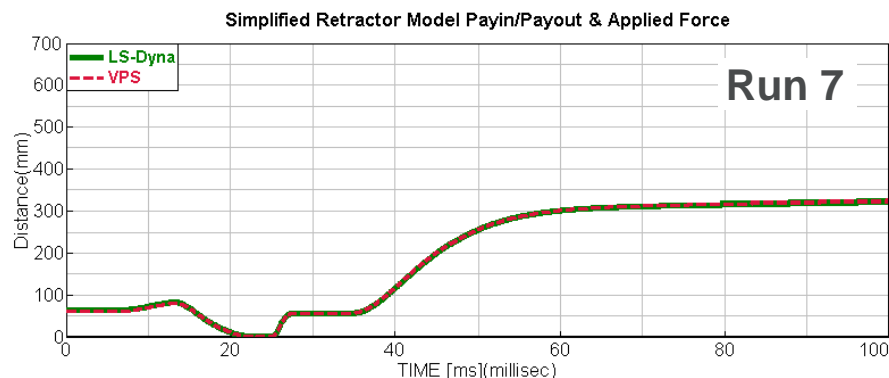
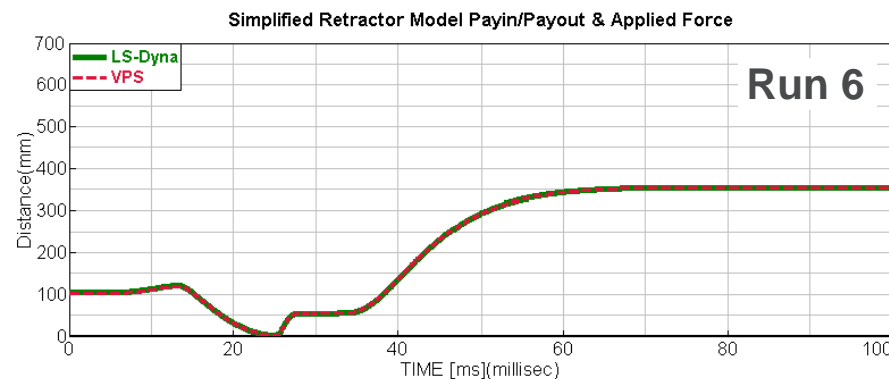
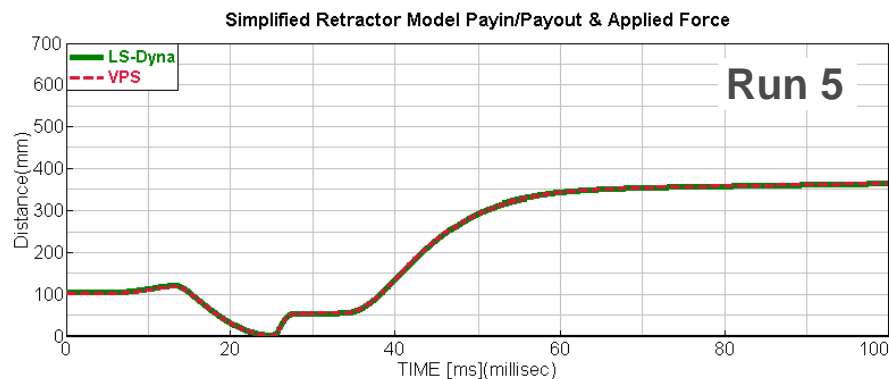


Name	1	2	3	4
R1Rttf	10	10	10	10
R1RPon	1	1	1	1
R1RPpow	0.8	1	1	0.8
R1LL1fo	2.2	2.2	2.8	3.64
R1LL2fo	10	10	10	10
R1LLup	0	0	0	0
R1LL1d	1000	1000	1000	1000
R1PPfo	0.02	0.02	0.02	0.02
R1PPtff	0	0	0	0
R LOADL	0.02	0.02	0.02	0.02
R LOADH1	2.6	2.6	3.3	4.1
R LOADH2	2.6	2.6	3.3	4.1
R LOADTS	1	1	5	5
R LOADTP	31	31	35	35
R LOADTM	1200	1200	1200	1200

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 5 to 8

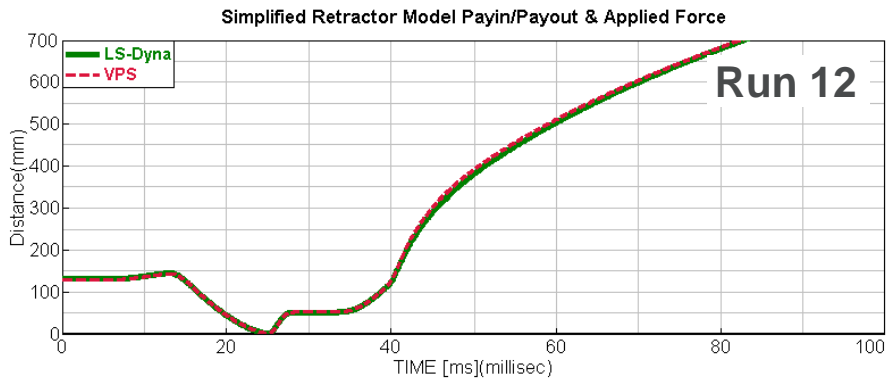
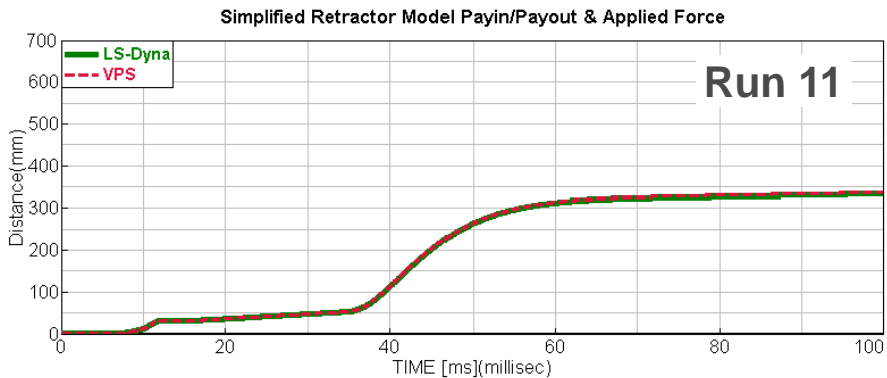
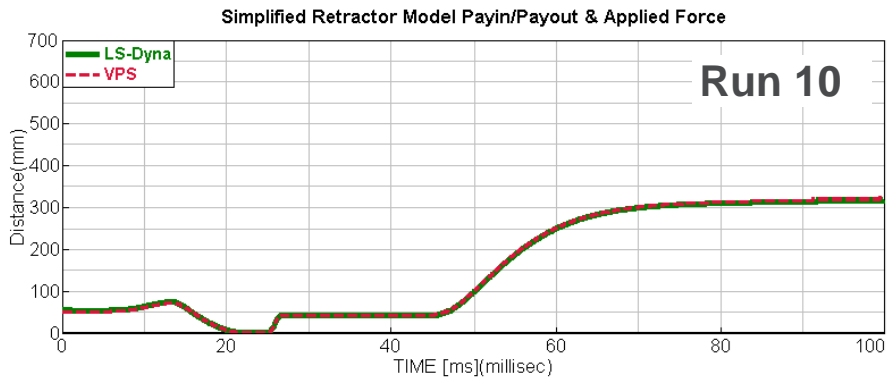
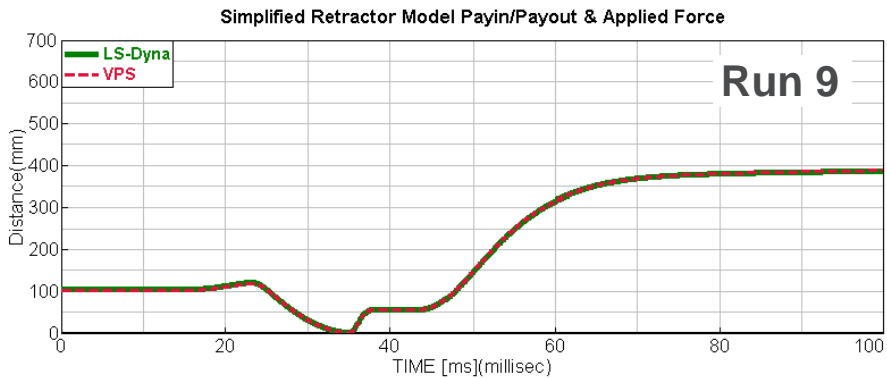


Name	5	6	7	8
R1Rttf	10	10	10	10
R1RPon	1	1	1	1
R1RPpow	1	1	1	1
R1LL1fo	3.64	3.64	4.5	3.1
R1LL2fo	10	10	10	10
R1LLup	0	0	0	0
R1LL1d	1000	1000	1000	1000
R1PPfo	0.02	0.02	0.02	0.02
R1PPtff	0	0	0	0
R LOADL	0.02	0.02	0.02	0.02
R LOADH1	4.1	4.1	4.9	3.45
R LOADH2	4.1	4.1	4.9	3.45
R LOADTS	5	5	5	5
R LOADTP	35	35	35	35
R LOADTM	1200	1200	1200	1200

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 9 to 12



X

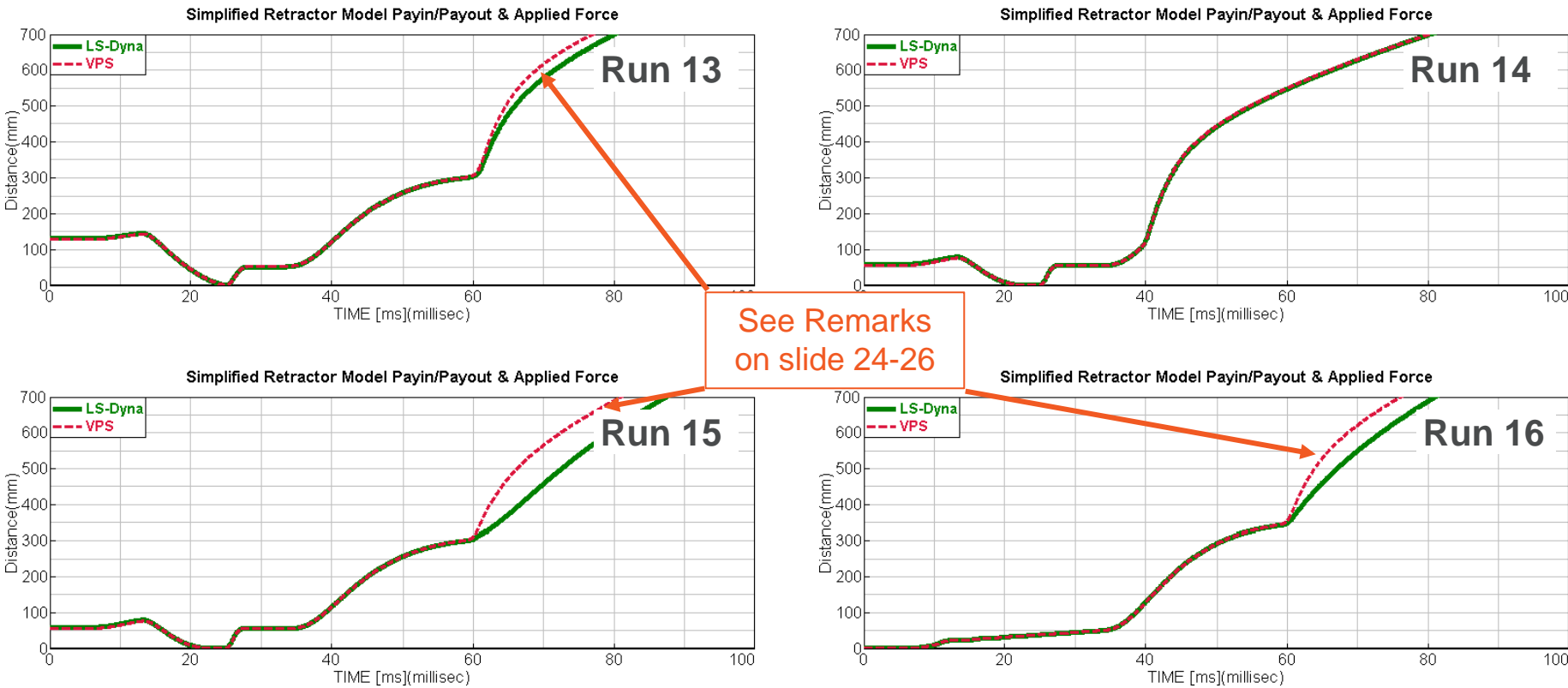
Name	9	10	11	12
R1Rttf	20	10	10	10
R1RPon	1	1	0	1
R1RPpow	1	1	1	1
R1LL1fo	3.6	6.5	6.5	3.2
R1LL2fo	10	10	10	1.3
R1LLup	0	0	0	0
R1LL1d	1000	1000	1000	70
R1PPfo	0.02	0.02	0.02	0.02
R1PPttf	0	0	0	0
R LOADL	0.02	0.02	0.02	0.02
R LOADH1	4.1	6.9	6.9	3.6
R LOADH2	4.1	6.9	4.1	1.5
R LOADTS	15	5	5	5
R LOADTP	45	45	35	35
R LOADTM	1200	1200	1200	40

x = Pretensioner deactivated

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 13 to 16 – before mass adjustments in spring materials



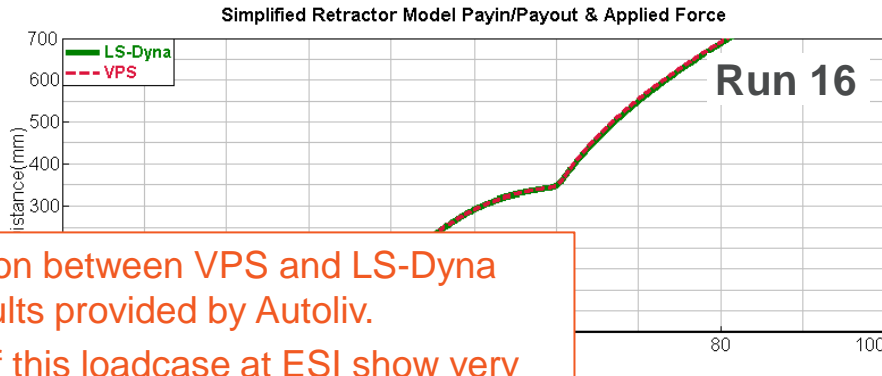
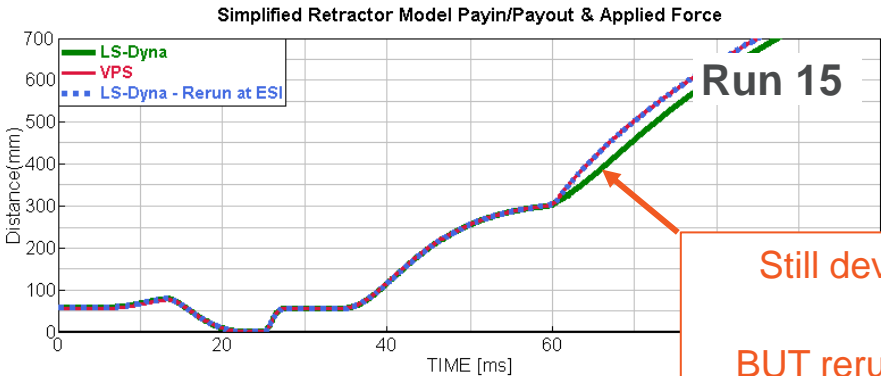
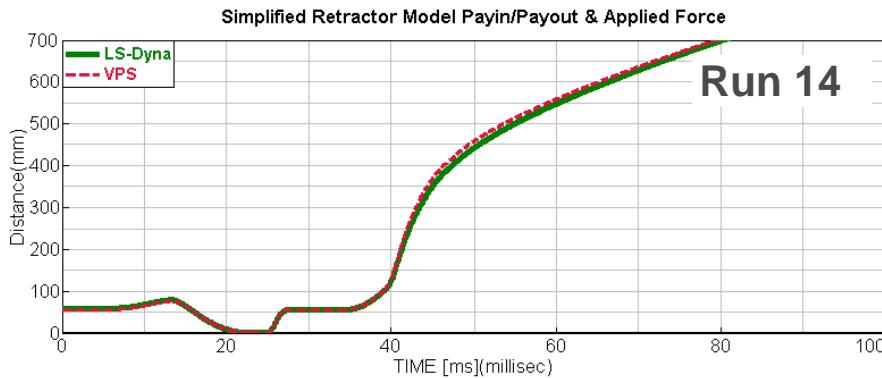
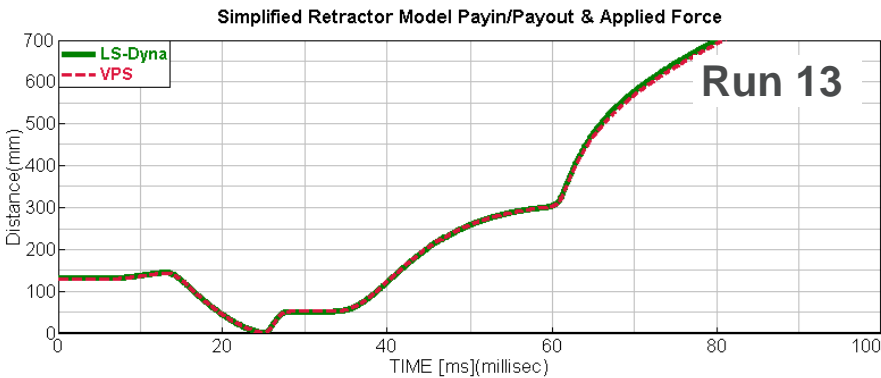
Name	13	14	15	16
R1Rttf	10	10	10	10
R1RPon	1	1	1	0
R1RPpow	1	1	1	1
R1LL1fo	3.2	4.6	4.6	4.55
R1LL2fo	1.3	1.9	1.9	1.9
R1LLup	0	0	0	0
R1LL1d	261	60	260	292
R1PPfo	0.02	0.02	0.02	0.02
R1PPttf	0	0	0	0
R LOADL	0.02	0.02	0.02	0.02
R LOADH1	3.6	5	5	5
R LOADH2	1.5	2.1	2.1	2.1
R LOADTS	5	5	5	5
R LOADTP	35	35	35	35
R LOADTM	61	40	60	60

x = Pretensioner deactivated

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 13 to 16 – after mass adjustments in spring materials



Still deviation between VPS and LS-Dyna results provided by Autoliv.
BUT rerun of this loadcase at ESI show very good correlation between the codes

x

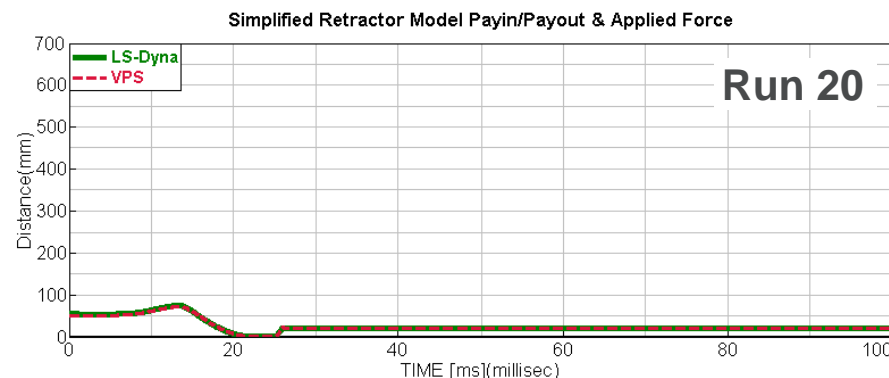
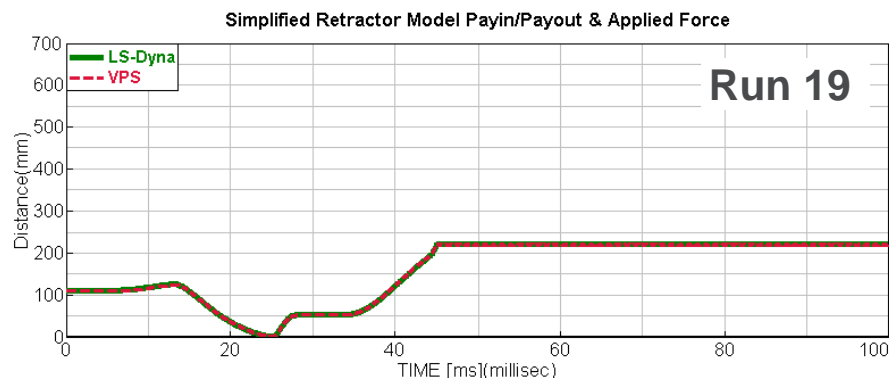
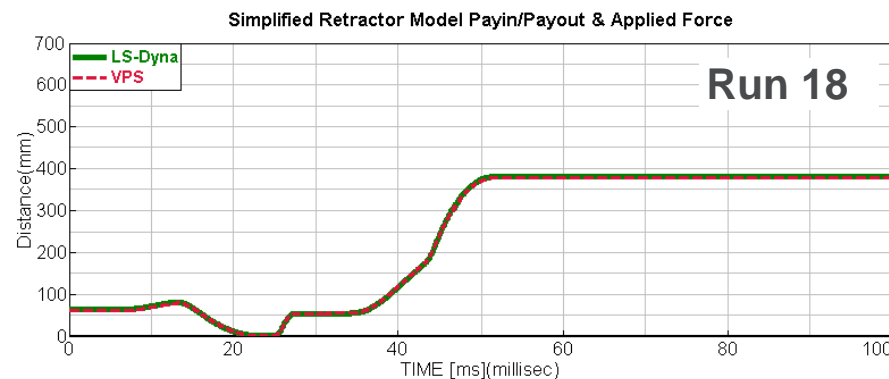
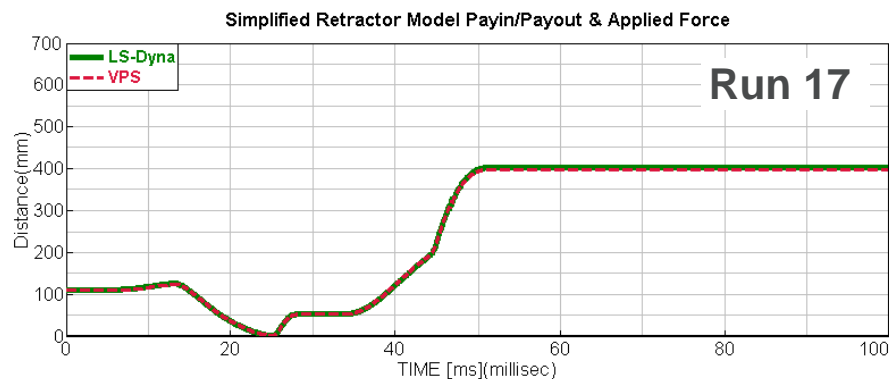
Name	13	14	15	16
R1Rttf	10	10	10	10
R1RPon	1	1	1	0
R1RPpow	1	1	1	1
R1LL1fo	3.2	4.6	4.6	4.55
R1LL2fo	1.3	1.9	1.9	1.9
R1LLup	0	0	0	0
R1LL1d	261	60	260	292
R1PPfo	0.02	0.02	0.02	0.02
R1PPttf	0	0	0	0
R LOADL	0.02	0.02	0.02	0.02
R LOADH1	3.6	5	5	5
R LOADH2	1.5	2.1	2.1	2.1
R LOADTS	5	5	5	5
R LOADTP	35	35	35	35
R LOADTM	61	40	60	60

x = Pretensioner deactivated

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 17 to 20

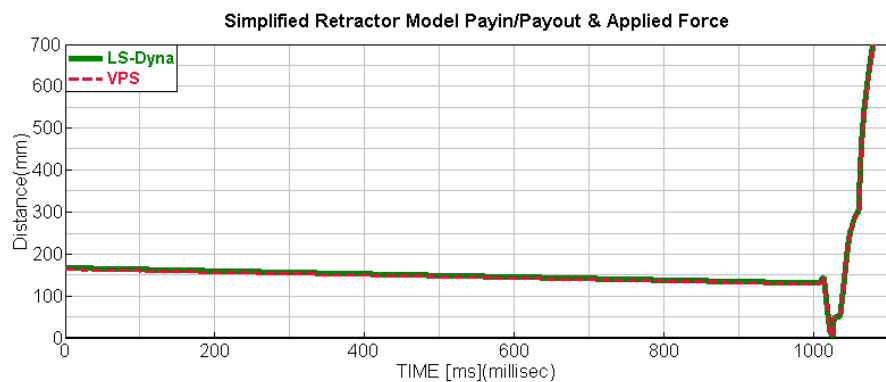
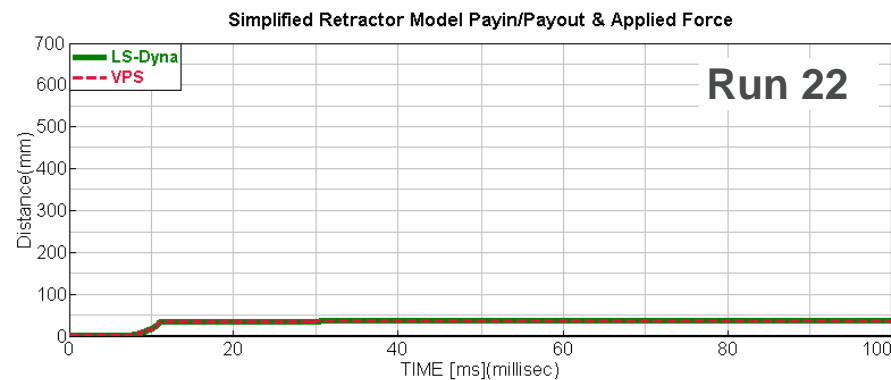
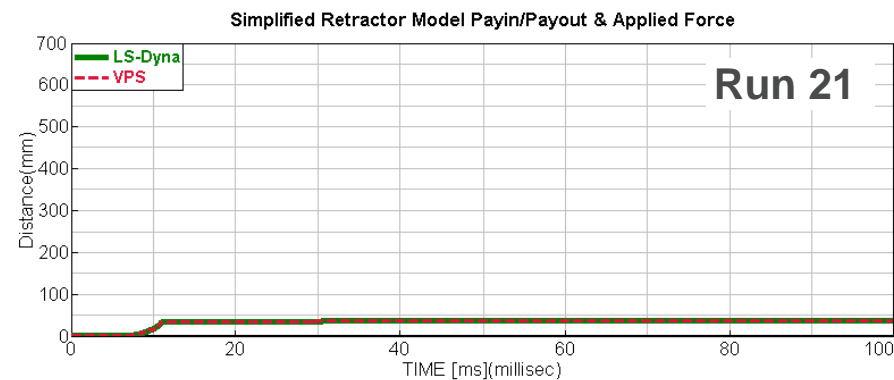


Name	17	18	19	20
R1Rttf	10	10	10	10
R1RPon	1	1	1	1
R1RPpow	0.95	0.95	0.95	1
R1LL1fo	3.3	4.2	3.3	50
R1LL2fo	8.1	6.5	50	10
R1LLup	1	1	1	0
R1LL1d	173	153	173	1000
R1PPfo	0.02	0.02	0.02	0.02
R1PPtff	0	0	0	0
R LOADL	0.02	0.02	0.02	0.02
R LOADH1	3.7	4.6	3.7	6.9
R LOADH2	8.5	7	8.5	6.9
R LOADTS	5	5	5	5
R LOADTP	35	35	35	45
R LOADTM	44	43	44	1200

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 21 to 23



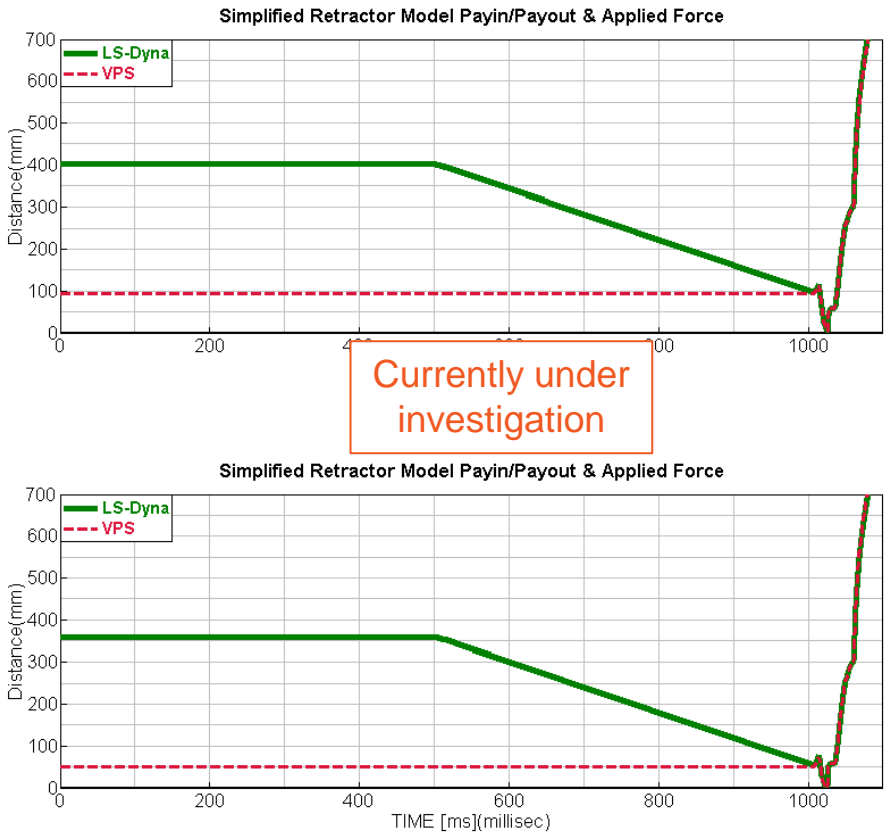
	X	X	
Name	21	22	23
R1Rttf	10	10	1010
R1RPon	0	0	1
R1RPpow	1	1	1
R1LL1fo	50	50	3.2
R1LL2fo	10	10	1.3
R1LLup	0	0	0
R1LL1d	1000	1000	261
R1PPfo	0.02	0.02	0.02
R1PPttf	0	0	0
R LOADL	0.02	0.02	0.02
R LOADH1	10	10	3.6
R LOADH2	4.1	4.1	1.5
R LOADTS	5	5	1005
R LOADTP	35	35	1035
R LOADTM	1200	1200	1061

x = Pretensioner deactivated

Model update in accordance with latest LS-Dyna model

Performance comparison to LS-Dyna model - Results

- Run 24 to 25



Run 24

Run 25

	y	y
Name	24	25
R1Rttf	1010	1010
R1RPon	1	1
R1RPpow	1	1
R1LL1fo	3.2	3.95
R1LL2fo	1.3	1.55
R1LLup	0	0
R1LL1d	261	261
R1PPfo	0.5	0.5
R1PPttf	500	500
R LOADL	0.48	0.48
R LOADH1	3.6	4.35
R LOADH2	1.5	1.75
R LOADTS	1005	1005
R LOADTP	1035	1035
R LOADTM	1061	1061

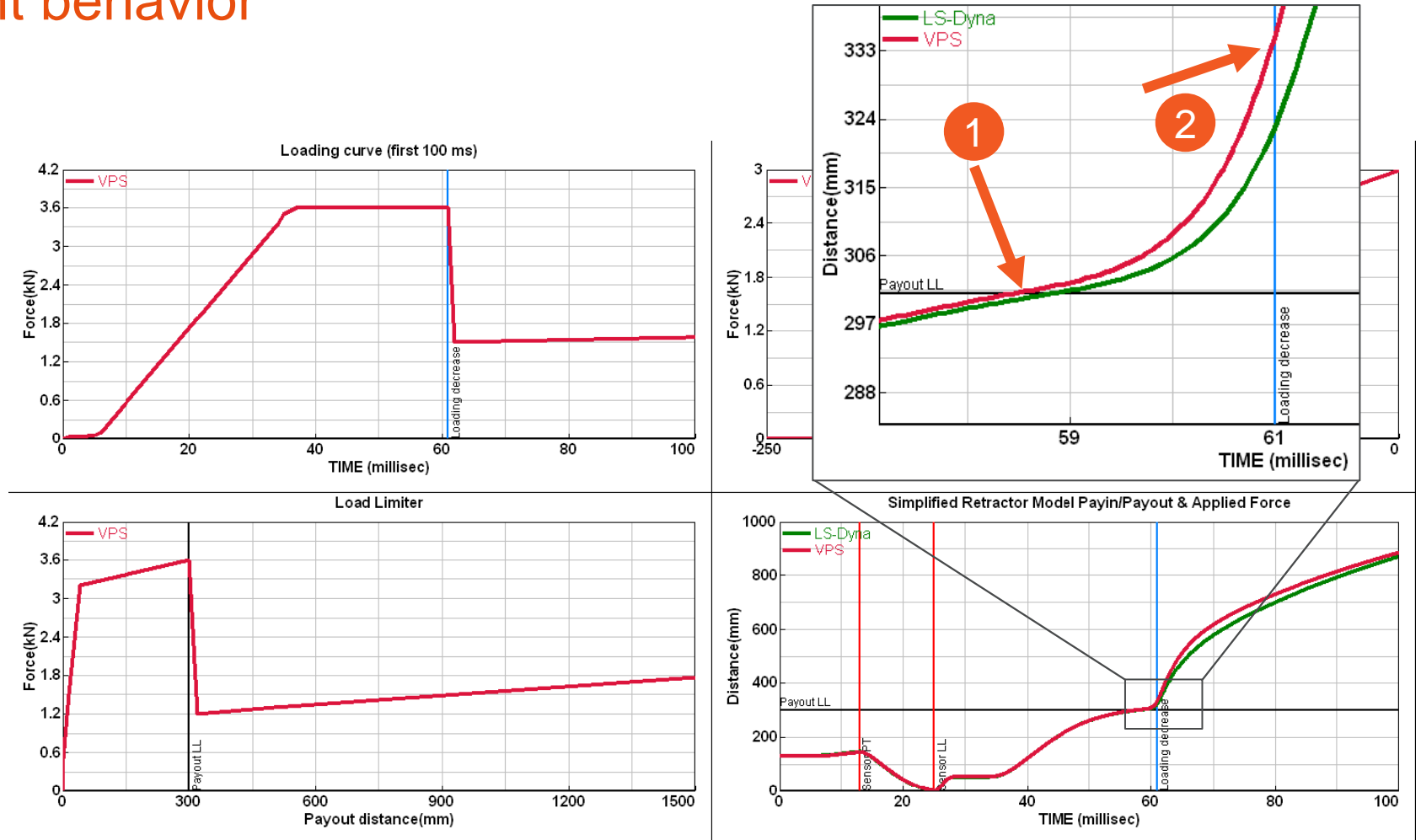
y = Pre-Pretensioner at time > 0ms

Model update in accordance with latest LS-Dyna model

Detailed look into different behavior

- Autoliv generic belt retractor
 - Loadcase setup 13
 - VPS:
 - 1 1mm more pullout when reaching “Payout LL” (0.35ms earlier)
 - 2 Larger pullout due high loading until the decrease of loading at 61ms

-> Loadcase setup is very sensitive



Model update in accordance with latest LS-Dyna model

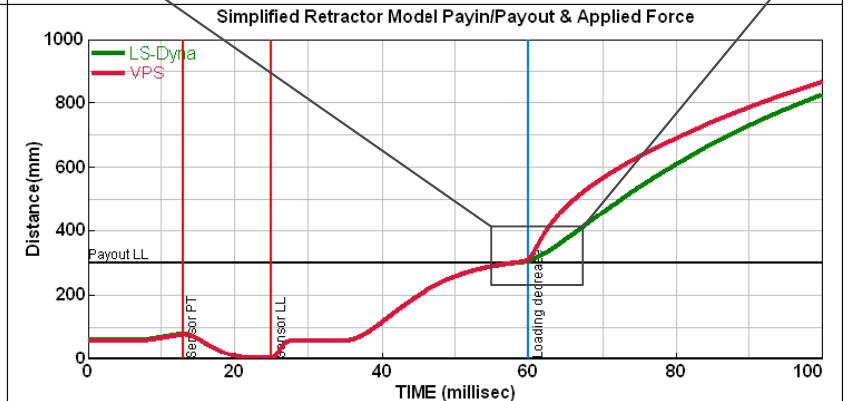
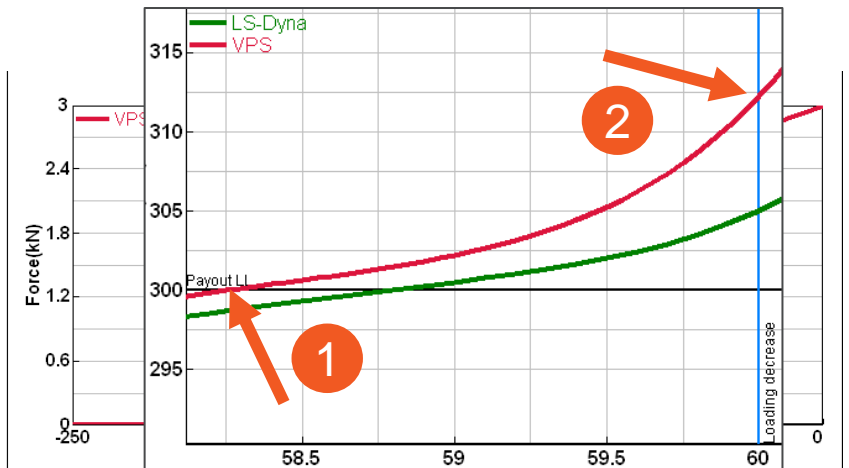
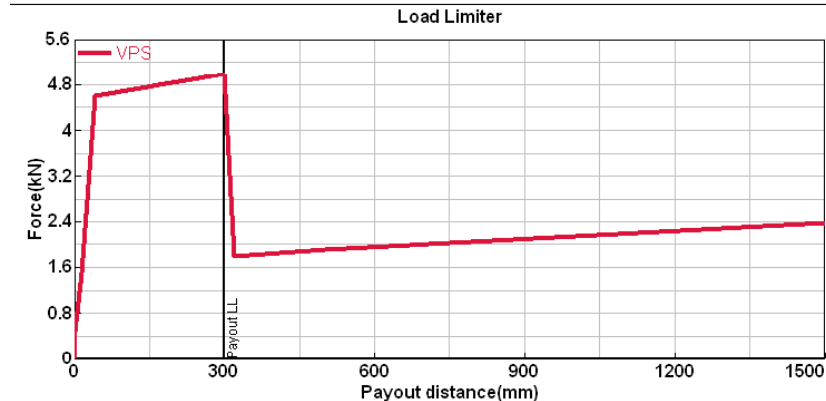
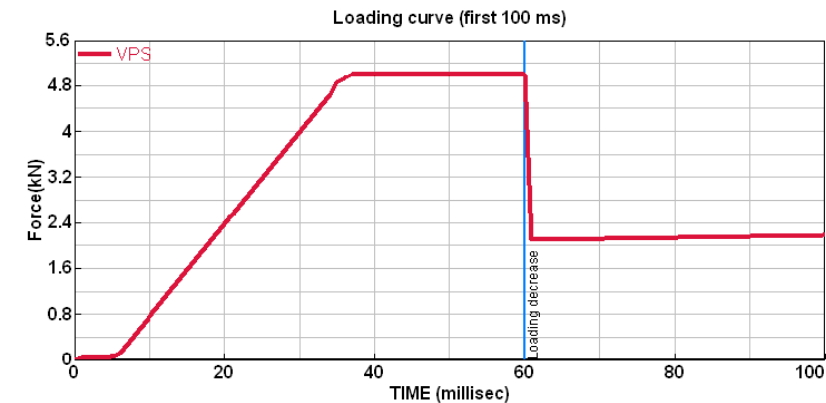
Detailed look into different behavior

- Autoliv generic belt retractor

- Loadcase setup 15

- VPS:

- 1 • 1.2mm more pullout when reaching “Payout LL” (0.5ms earlier)
- 2 • Larger pullout due high loading until the decrease of loading at 60ms
-> Loadcase setup is very sensitive



Model update in accordance with latest LS-Dyna model

Detailed look into different behavior

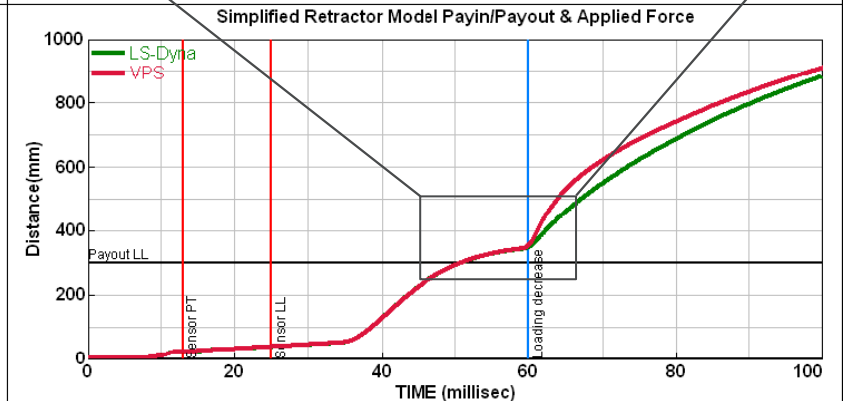
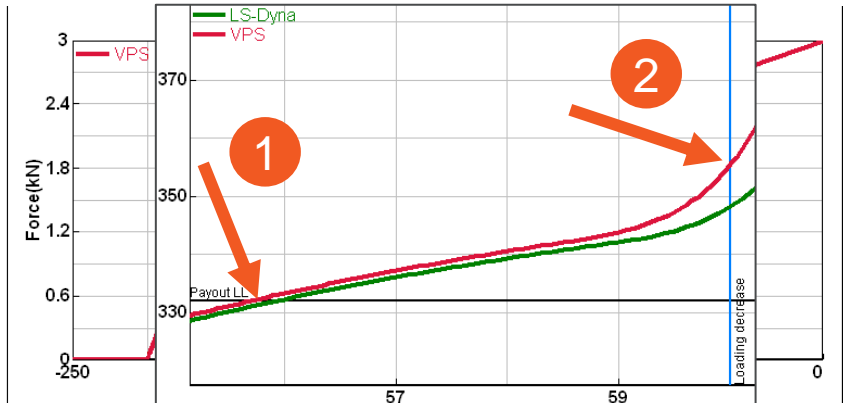
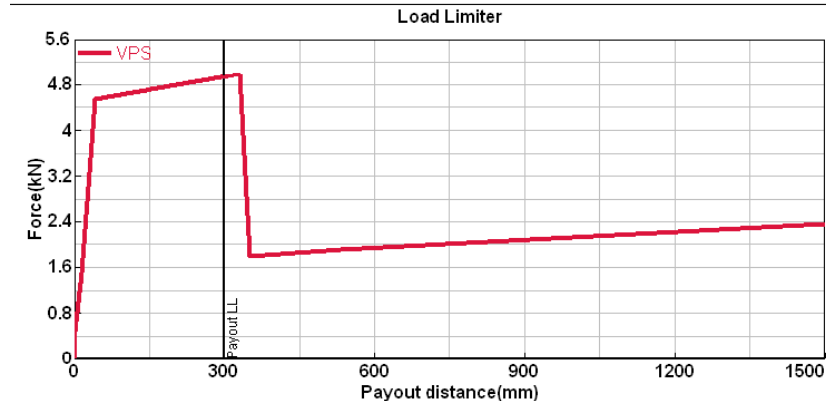
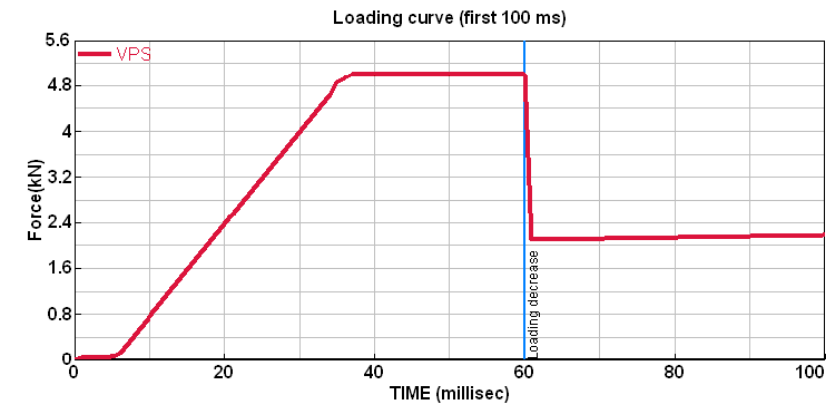
- Autoliv generic belt retractor

- Loadcase setup 16

- VPS:

- 1. 1.0mm more pullout when reaching “Payout LL” (0.25ms earlier)
- 2. Larger pullout due high loading until the decrease of loading at 60ms

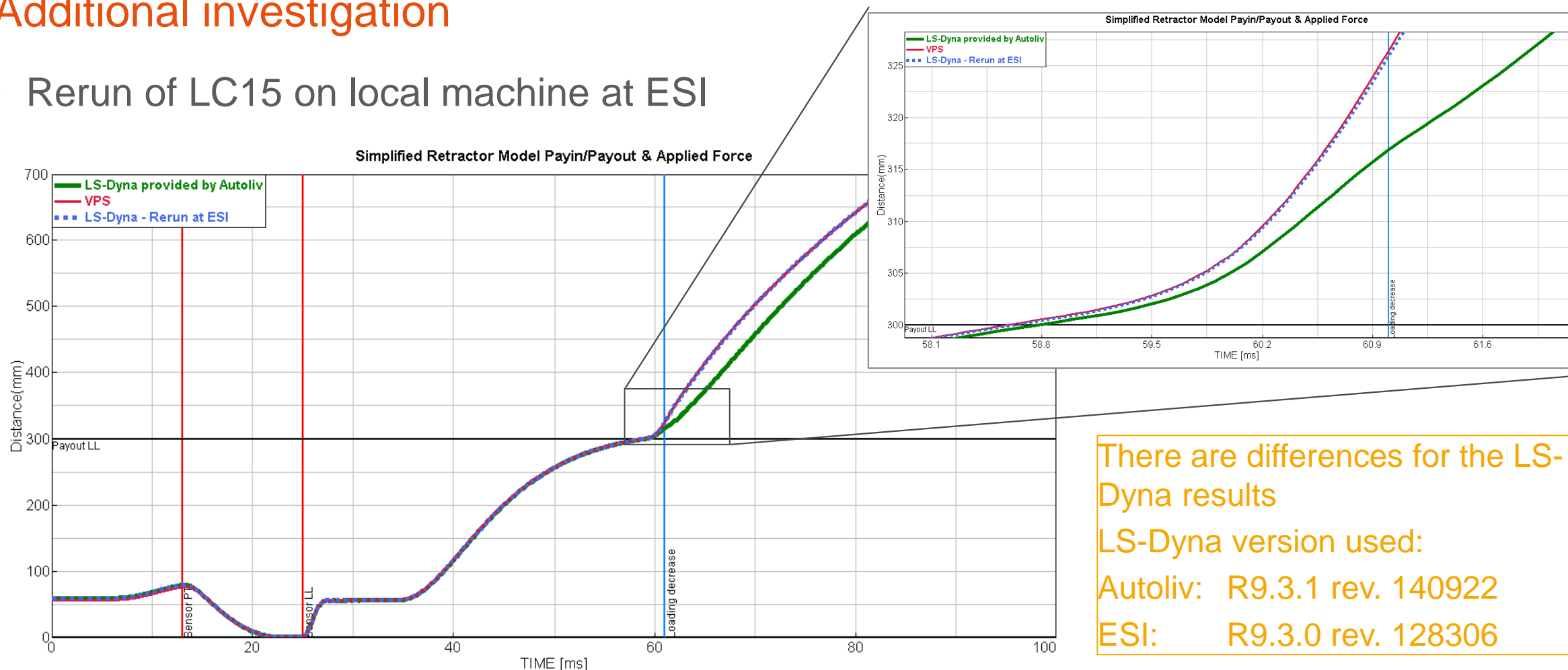
-> Loadcase setup is very sensitive



Model update in accordance with latest LS-Dyna model

Additional investigation

- Rerun of LC15 on local machine at ESI



There are differences for the LS-Dyna results

LS-Dyna version used:

Autoliv: R9.3.1 rev. 140922

ESI: R9.3.0 rev. 128306

Model update in accordance with latest LS-Dyna model

Final remarks

- Very good correlation if pre-pretensioning starts at $t = 0\text{ms}$
 - This BETA version is available
 - with a restriction to not be able to use pre-pretensioning starting at $t > 0\text{ms}$
 - Further internal investigations with central support and developers on LC24+25 in parallel
 - Differences in the curves of the payout have been observed in the LS-Dyna model for LC15, see also slide 27
 - Results provided by Autoliv, LS-Dyna Version R9.3.1 rev. 140922
 - Results recreated by ESI, LS-Dyna Version R9.3.0 rev. 128306

Thank you!

Any Questions?

support.esigmbh@esi-group.com