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KNS 2017 Spring

춘계학술발표회

Constructional requirements for protective structures for mid- and long-term dry intermediate storage of spent fuel assemblies and heat generating radioactive waste in casks

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KNS 2017 Spring, Jeju, 05/19/2017, session 8C

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Introduction

Storage of radioactive waste material in Germany:

- 2022 the last 2 remaining NPPs will be shut down
- 2031 at the earliest, a final repository site will be determined
- 2040 the operating license of the last remaining central intermediate storage facility will expire
- 2050 at the earliest, the final repository site will be operational
- It will take at least one more decade to safely store all casks

⇨ **An interim solution is needed to cover the time period between 2040 and the day when the last cask will be safely stored in the final repository**

Protection objectives

In accordance to the IAEA safety documents, an interim storage facility has to fulfill the following requirements:

1. Maintenance of subcriticality
2. Removal of residual heat
3. Ensure radiation protection –
   ALARA-principle "***A**s **L**ow **A**s **R**easonably **A**chievable*"
4. Maintain containment over the entire service life, including ensured transportability of casks

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Safety requirements – safe containment of SNF / HLW

The German federal ministry for nuclear safety defines a technical safety concept in accordance with the German atomic energy act as follows:

1. "…radioactive substances in nuclear power plants have to be contained several times by technical barriers or restraint functions…"
2. "A defense-in-depth concept is to be implemented which ensures the fulfillment of the protection objectives and the maintenance of the barriers and restraint functions on several staggered security levels as well as for internal and external impacts."

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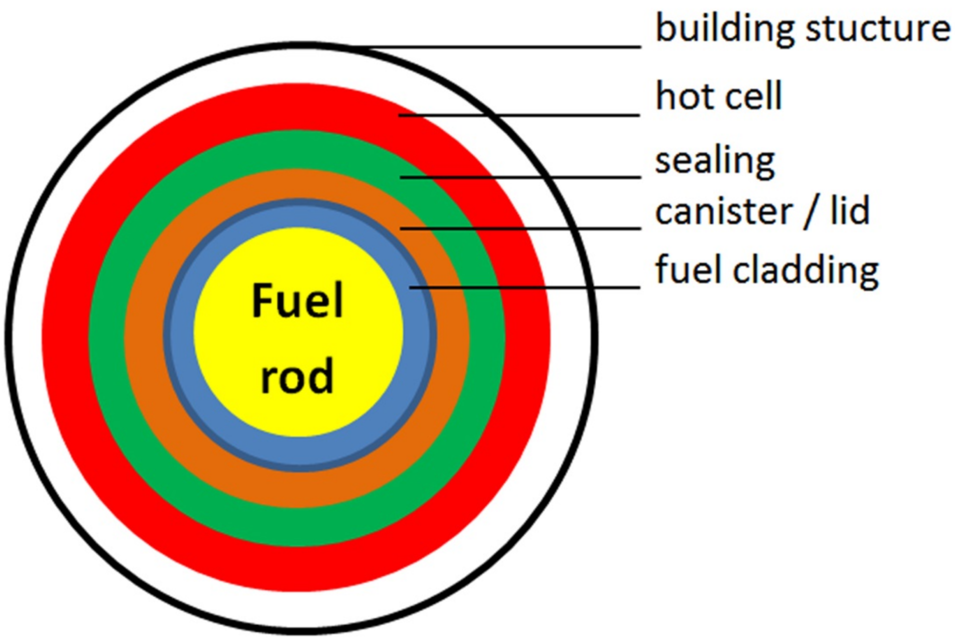
Safety requirements – safe containment of SNF / HLW

Technical barriers or restraining functions in nuclear safety:



Safety requirements – safe containment of SNF / HLW

Defense in depth concept in nuclear safety

Levels of defence in depth	Objective	Essential means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedures
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Source: IAEA, INSAG-10

Outlook

Realistic scenarios for the future could be:

1. To build one or more new centralised-, state-of-the-art dry interim storage facility(ies) for high and mid-level radwaste… **AND / OR**
2. To modernize the existing power plants' intermediate storage facilities to minimize transportation of casks

⇨ **Both scenarios would implement a reconsideration of the safety requirements that the building structures have to fulfill**

⇨ **Protection against higher threat levels and load cases like large aircraft impact and/or terrorist' attack have to be ensured in order to be politically acceptable**

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Safe containment of radioactive substances

Criticality safety

- Temporarily as well as permanent storage of nuclear fuel requires consideration of measures coming from standard DIN 25403-1 „Criticality safety in processing and handling fissile materials, Part 1: Principles”
- In case of an aircraft impact, the structure of the building has to ensure subcriticality

Safe containment of radioactive substances

Heat removal

- Temperatures of casks and inventories, as well as storage buildings have to remain below admissible limits
- Heat has to be dissipated passively to the environment by natural convection
- The protective structure has to provide adequate exhaust air openings
- Maximum design temperatures of the building structure have to be strictly observed

Safe containment of radioactive substances

Shielding and radiation protection

- Sufficient shielding is necessary for the protection of the population and the operating staff
- This can be reached through the design of the casks and hot cells and by appropriately designing the building structure
- Openings in the outer shell of the building have to be designed in accordance to the shielding aspect
- Any unnecessary radiation exposure or contamination of humans and the environment has to be avoided

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Constructional requirements

Generally accepted rules of building technology…

+ Consideration

  …of intended use > suitability and durability

  …of materials and components > life time aspect
+ Sufficient air-flow > removal of the decay heat
+ Temperature stress- and aging resistance
+ Surface coatings > easy decontamination
+ Sufficient temperature-, pressure-, wear- and tear-resistance > durability

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Constructional requirements

Generally accepted rules of building technology…

+ Base plate is able to withstand high loads
+ Sufficient crane loads
+ Shock-absorbing structures where load crash is possible
+ Storage and loading area form separate fire sections
+ Adjacent buildings like offices, labs, workshops etc. have to be built as separate fire sections

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New concepts for intermediate storage facilities

Licensing authorities in Germany increasingly tend to demand a multi-barrier-concept

The company Max Aicher Engineering developed a conceptual design for an intermediate storage building for high-level waste

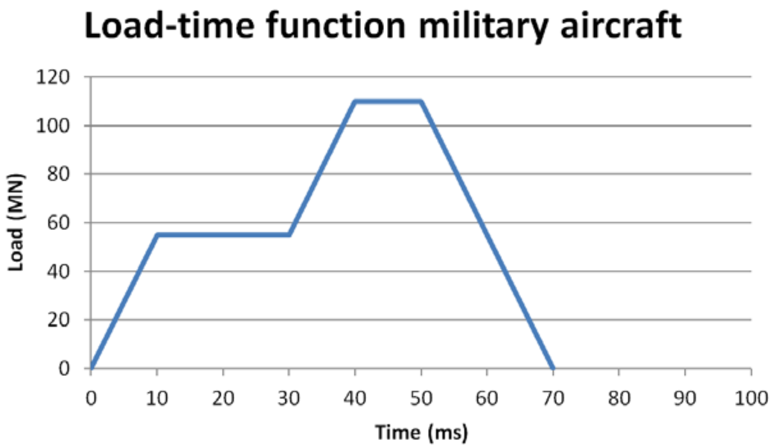
Outer dimensions of the building:

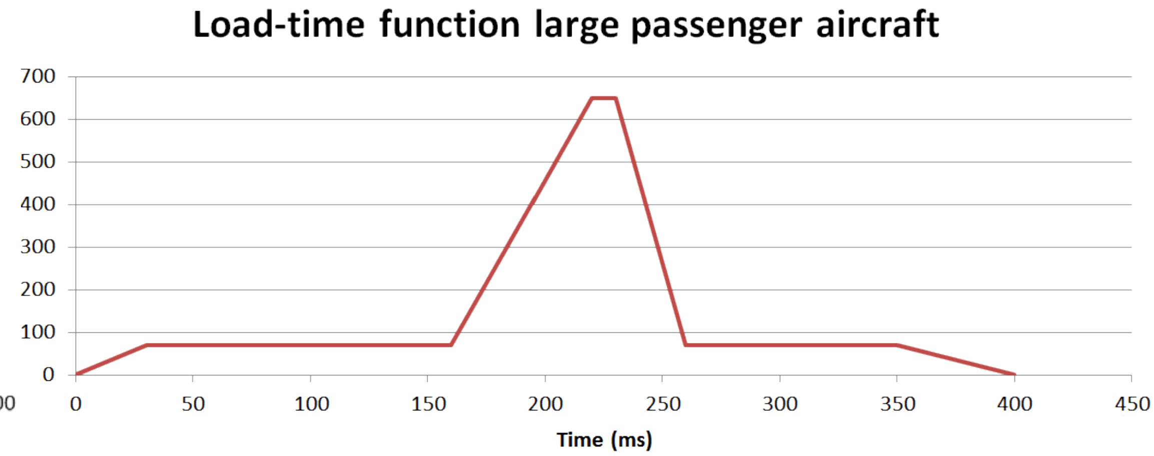
80 m length, 27 m width and a height of 18 m, fits 90 casks

New concepts for intermediate storage facilities

New concepts for intermediate storage facilities

Numerical simulations were made for several aircraft impact scenarios. Load-time-functions were chosen according to DIN 25449: “Reinforced and pre-stressed concrete components in nuclear facilities - Safety concept, actions, design and construction”





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New concepts for intermediate storage facilities

The impacts were simulated for the following scenarios:

a. a twin engine fighter jet on the roof of the building (square)
b. a twin engine fighter jet on the side wall of the building (square)
c. a large passenger aircraft on the side wall of the building (10°)

Case a. and b.:
McDonnell Douglas F4 Phantom, mass: 20 Mg, impact velocity: 215 m/s,

Case c.:
Airbus A340, mass: 300 Mg impact velocity: 175 m/s

note: The following pictures show stress levels by color and the magnified deformations (factor 50) generated by the FEM analysis (finite element method)

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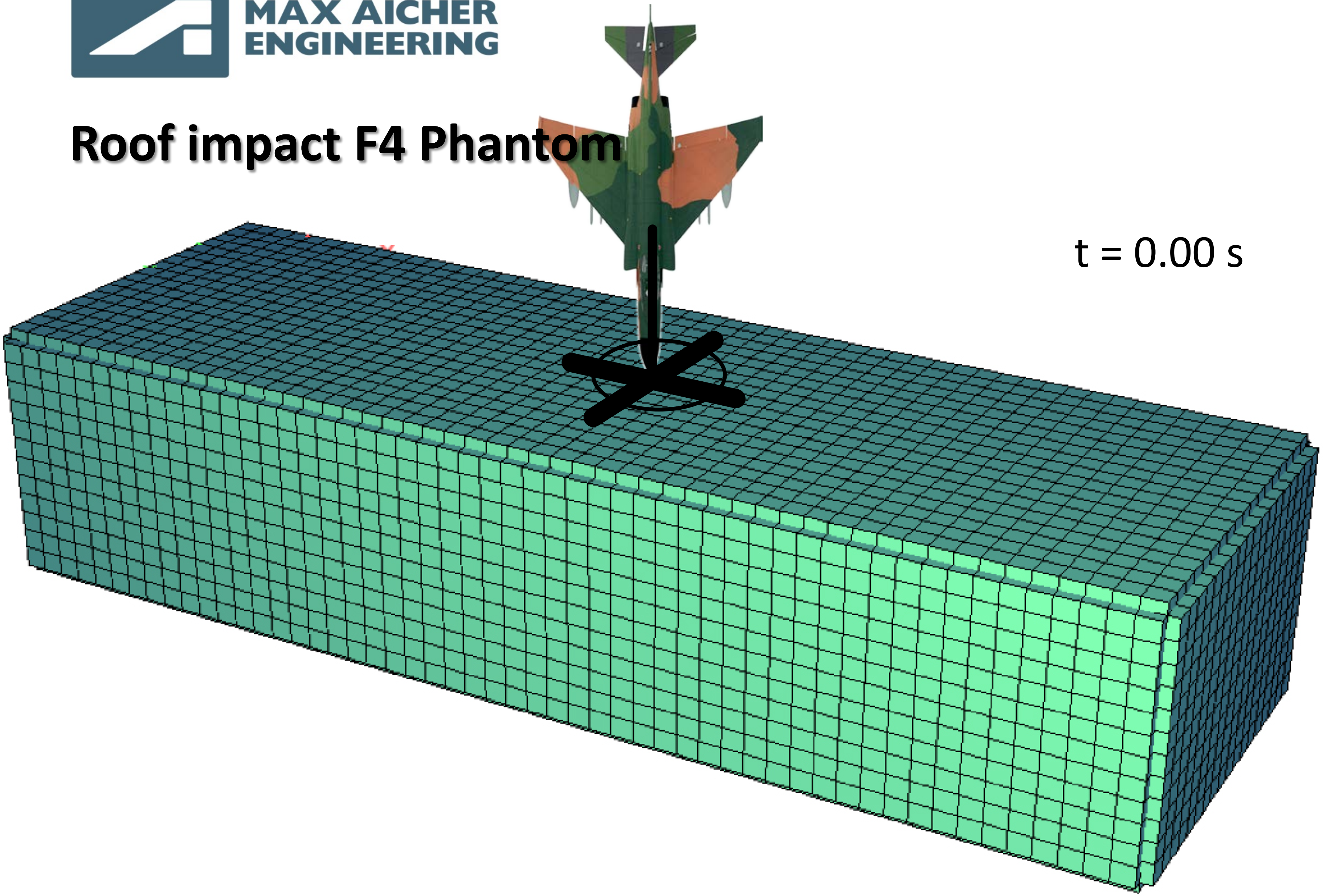
Roof impact F4 Phantom



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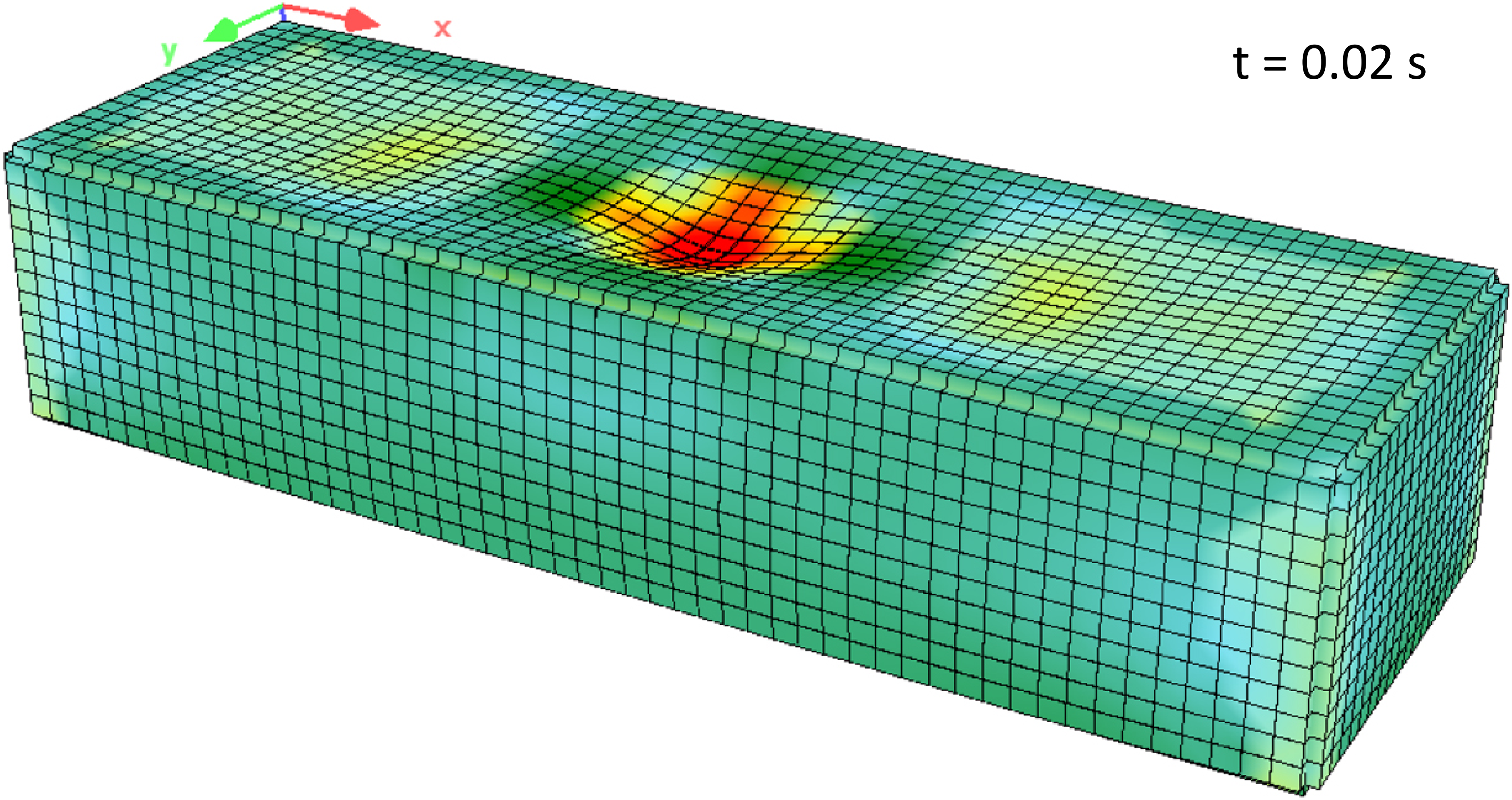
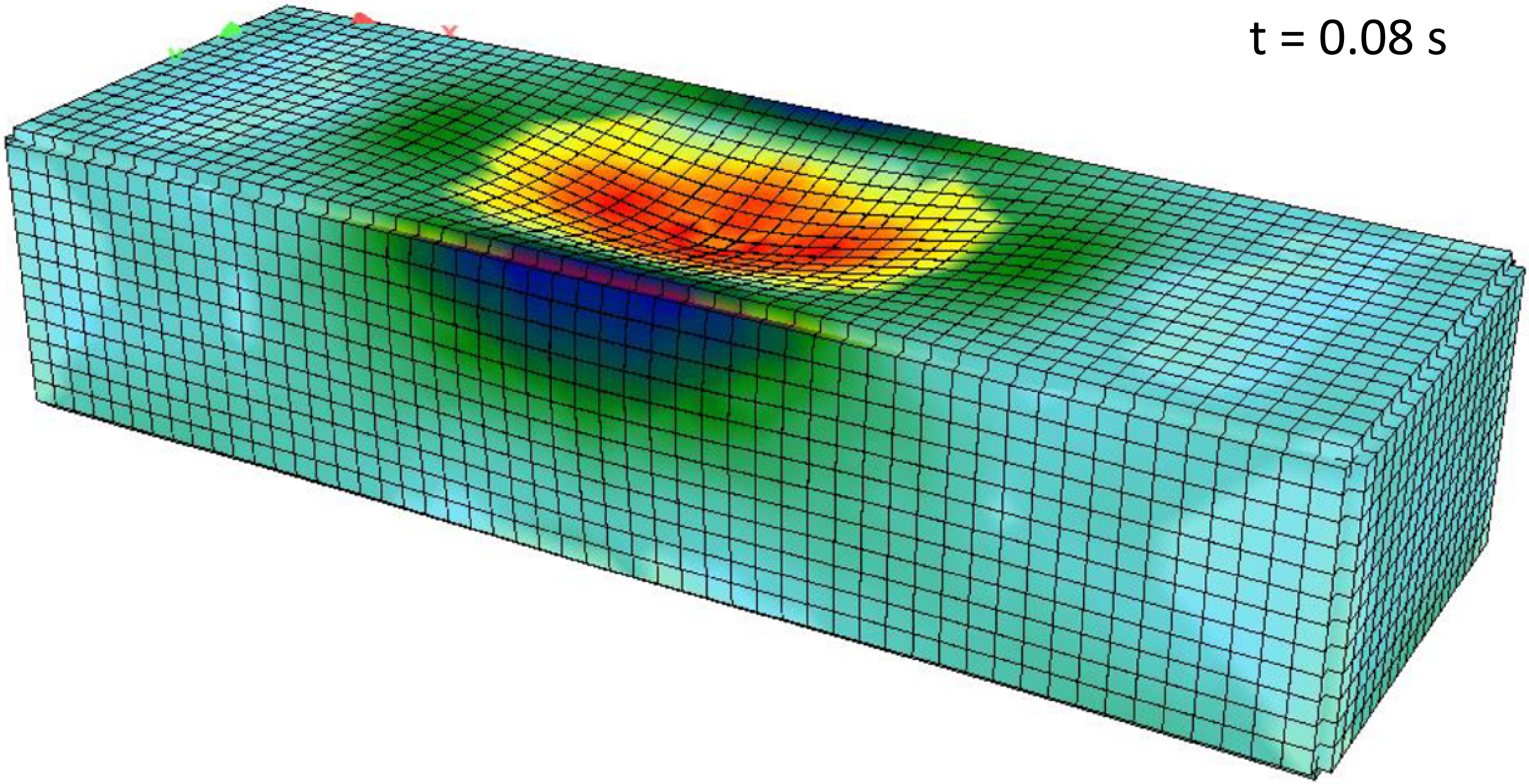
Roof impact F4 Phantom



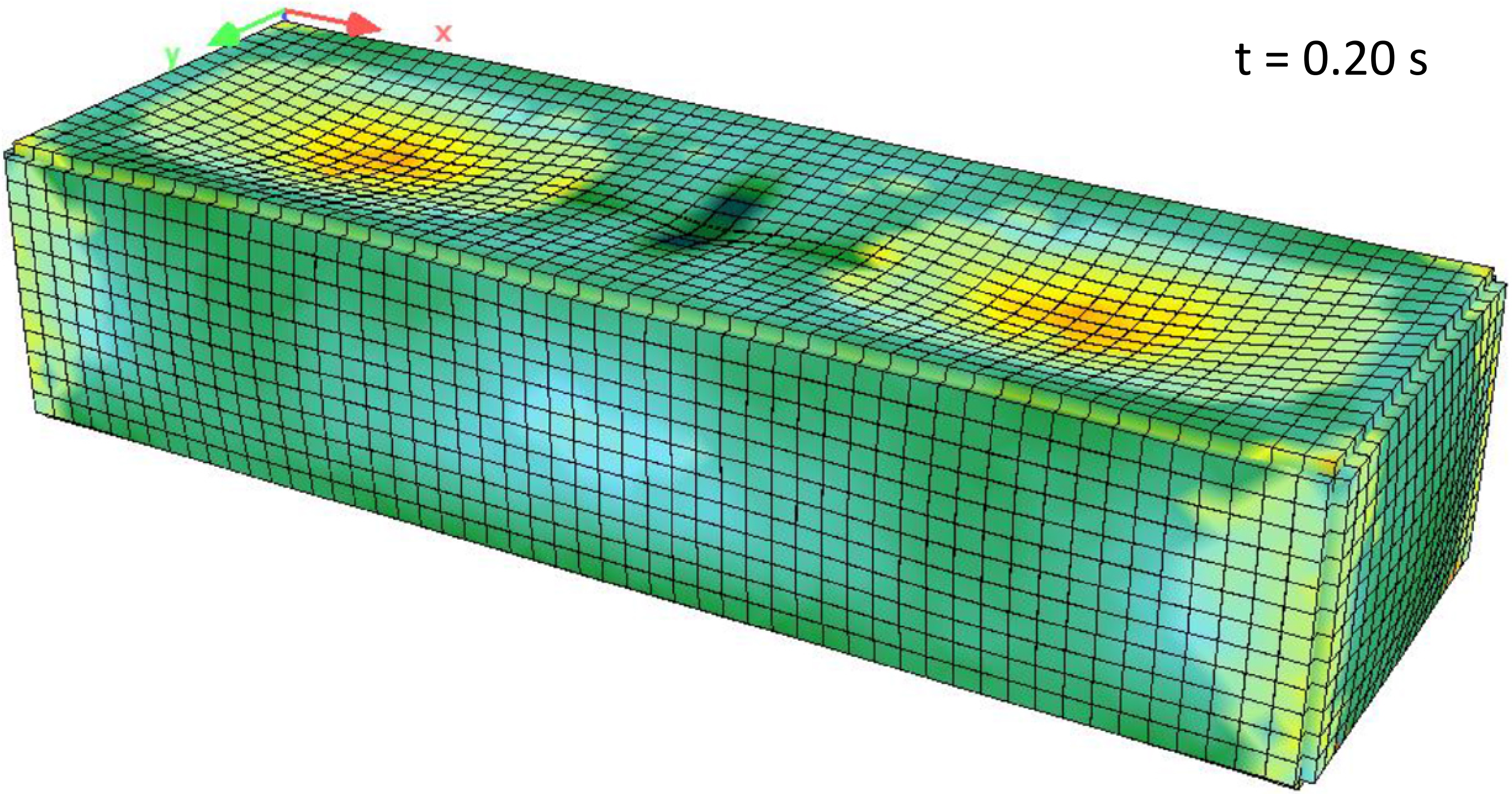
Roof impact F4 Phantom

t = 0.08 s



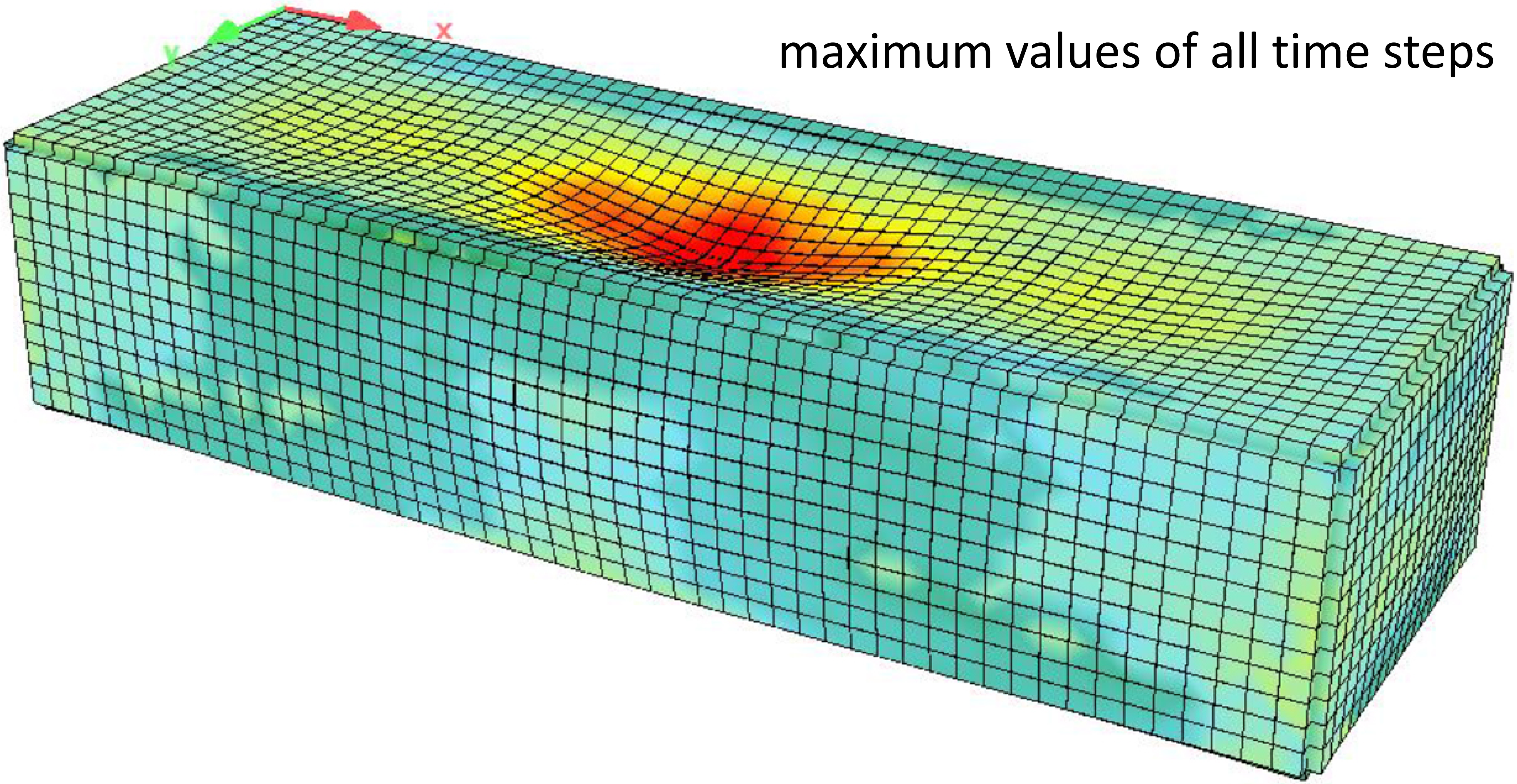
Roof impact F4 Phantom

t = 0.20 s



Roof impact F4 Phantom

maximum values of all time steps



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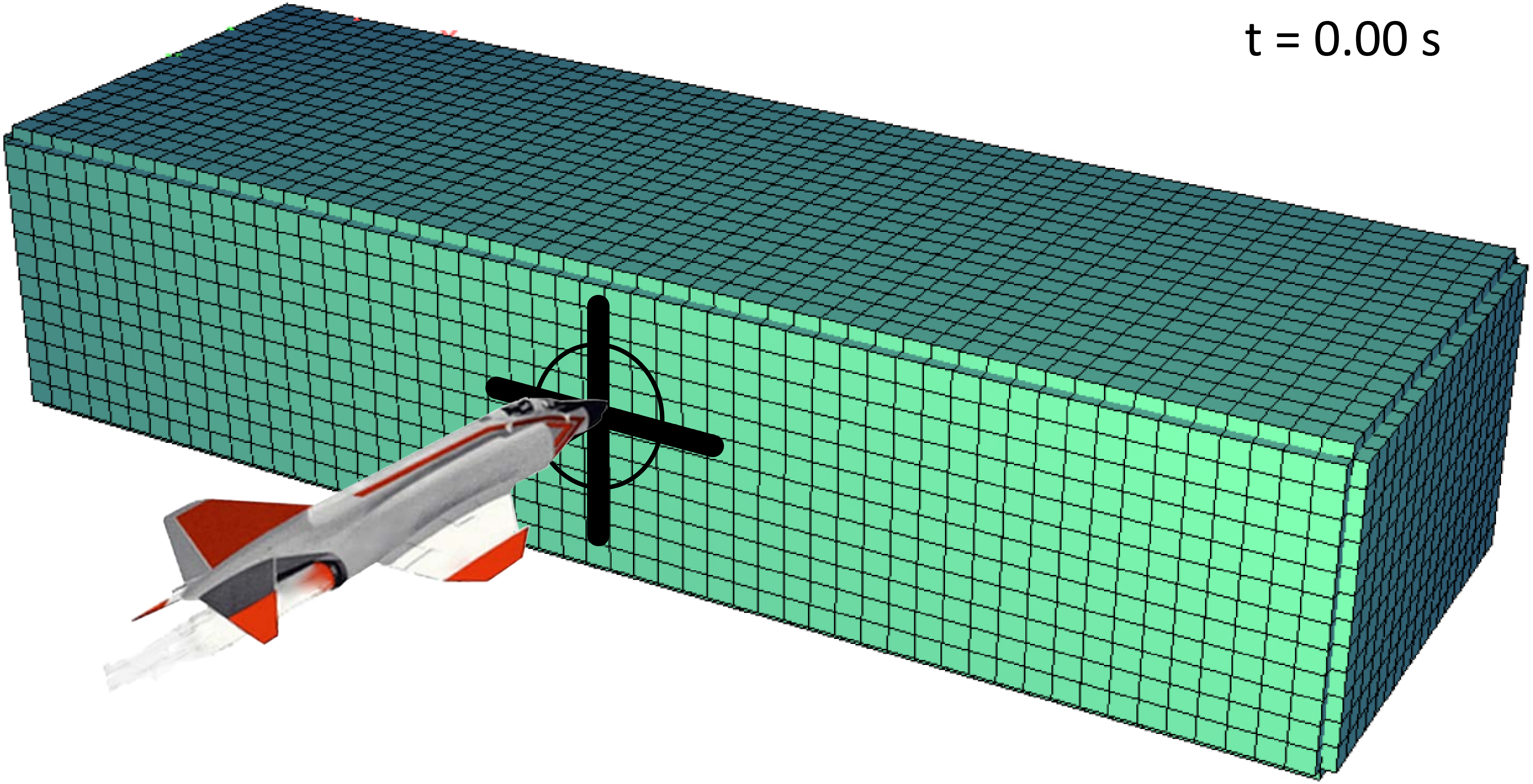
Wall impact F4 Phantom

t = 0.00 s



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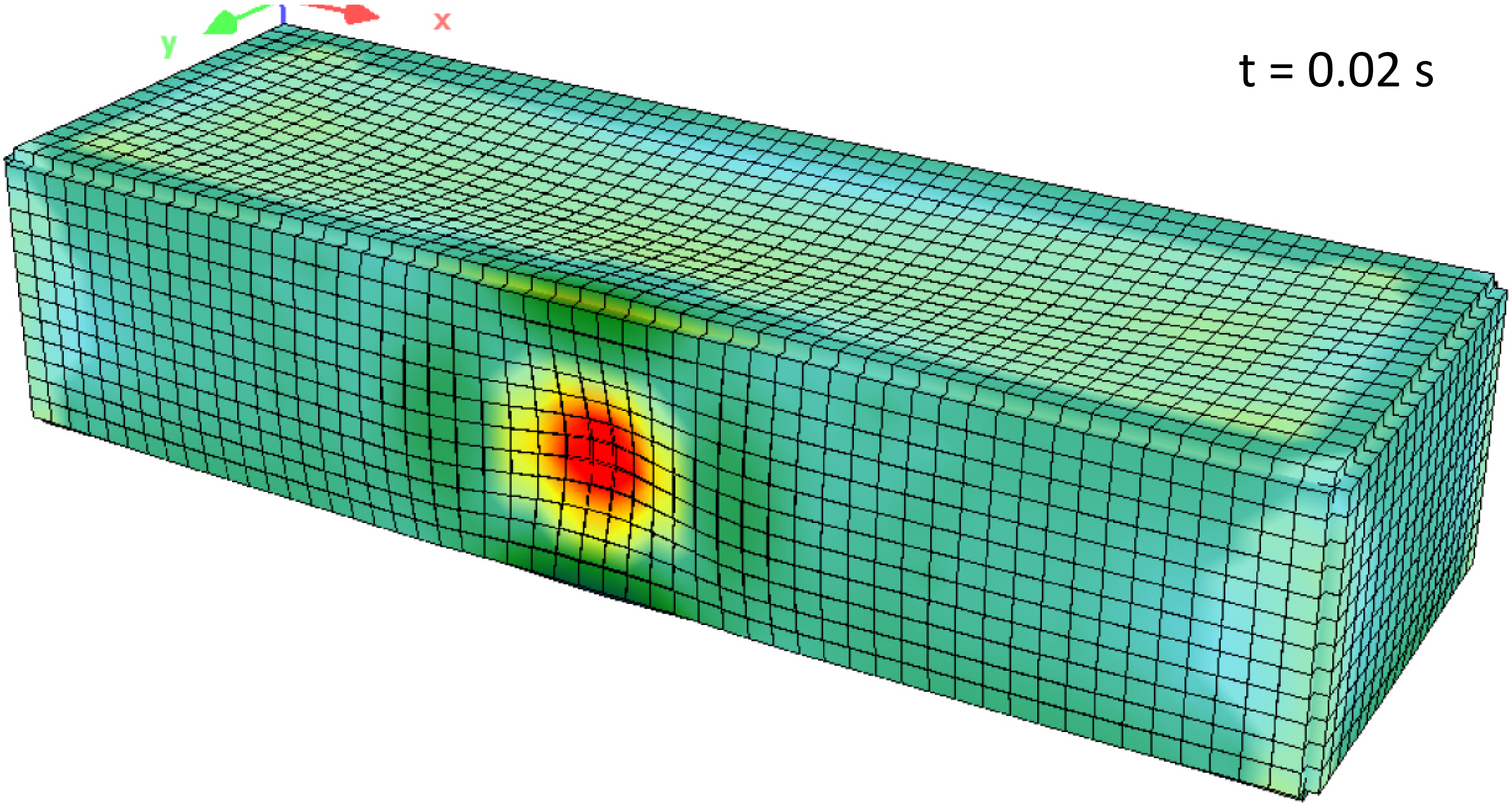
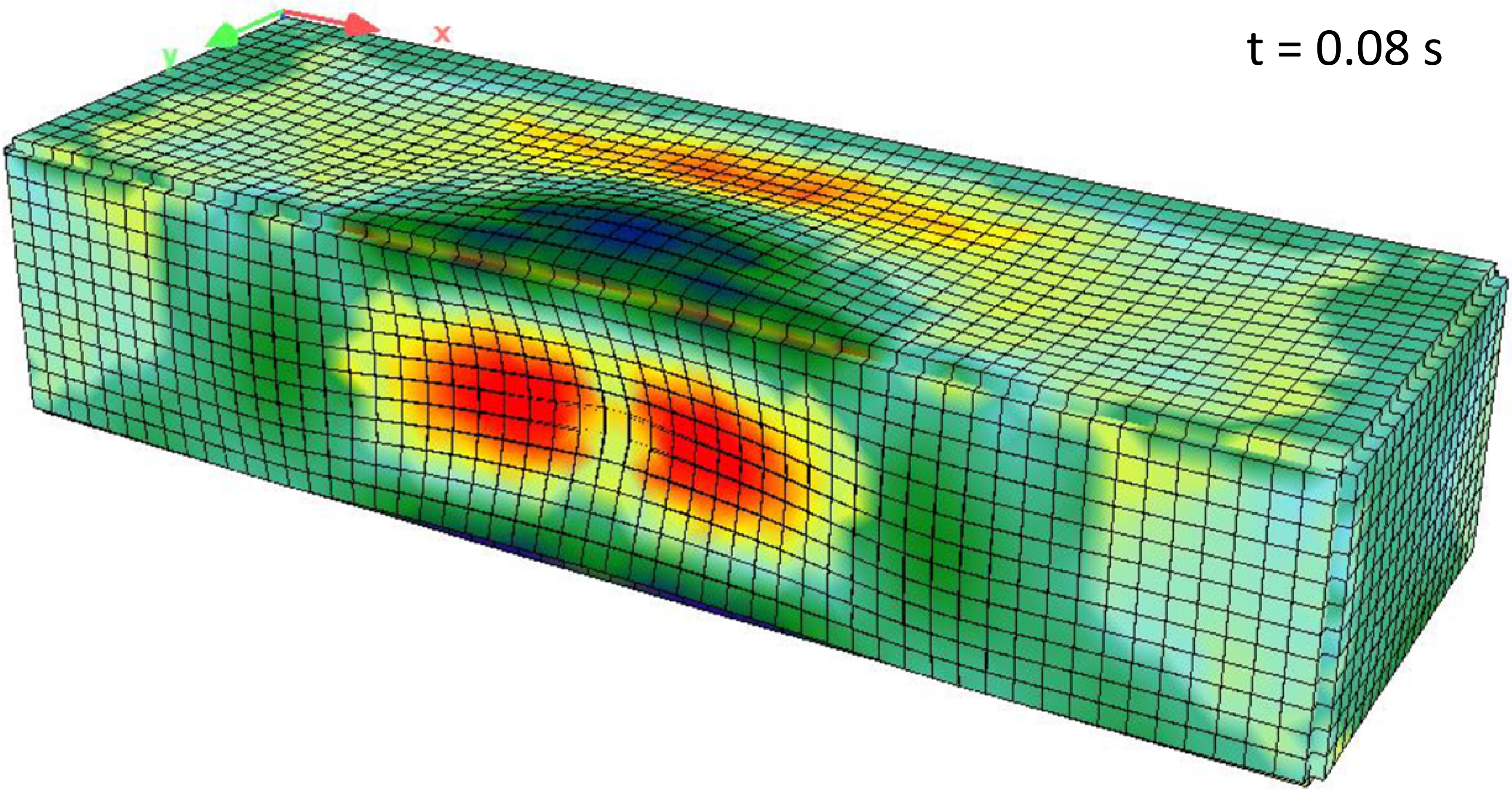
Wall impact F4 Phantom



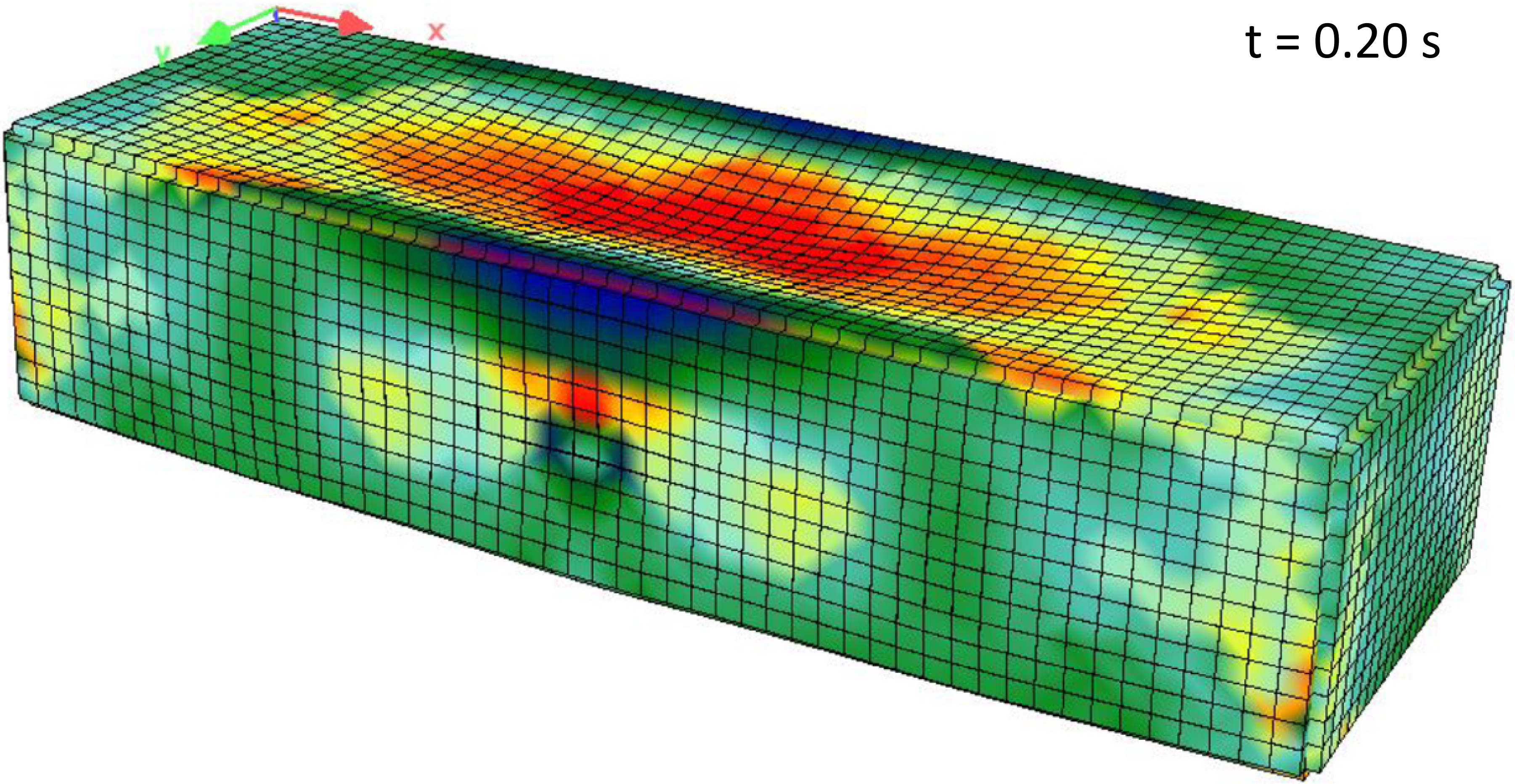
t = 0.02 s

Wall impact F4 Phantom



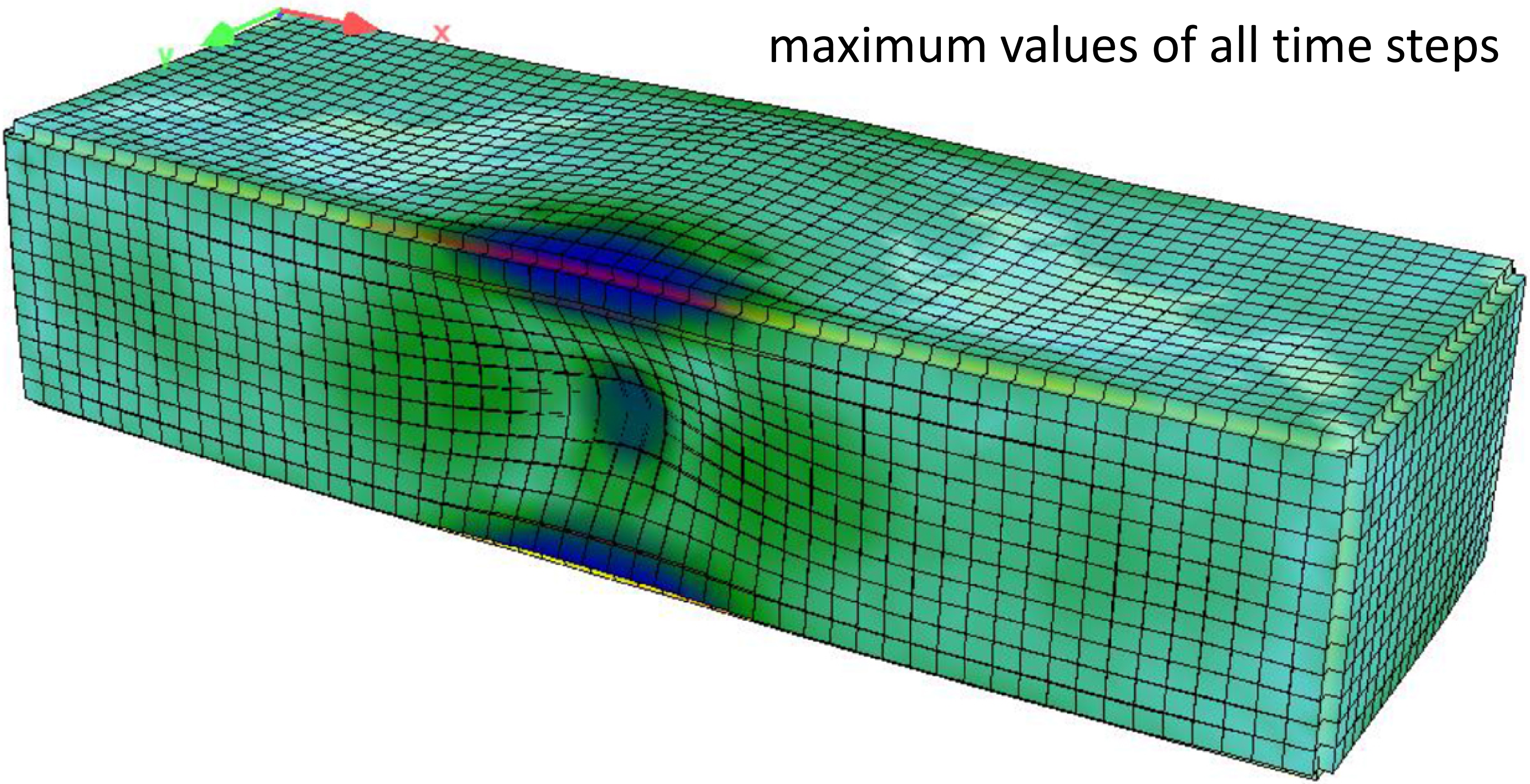
Wall impact F4 Phantom

t = 0.20 s

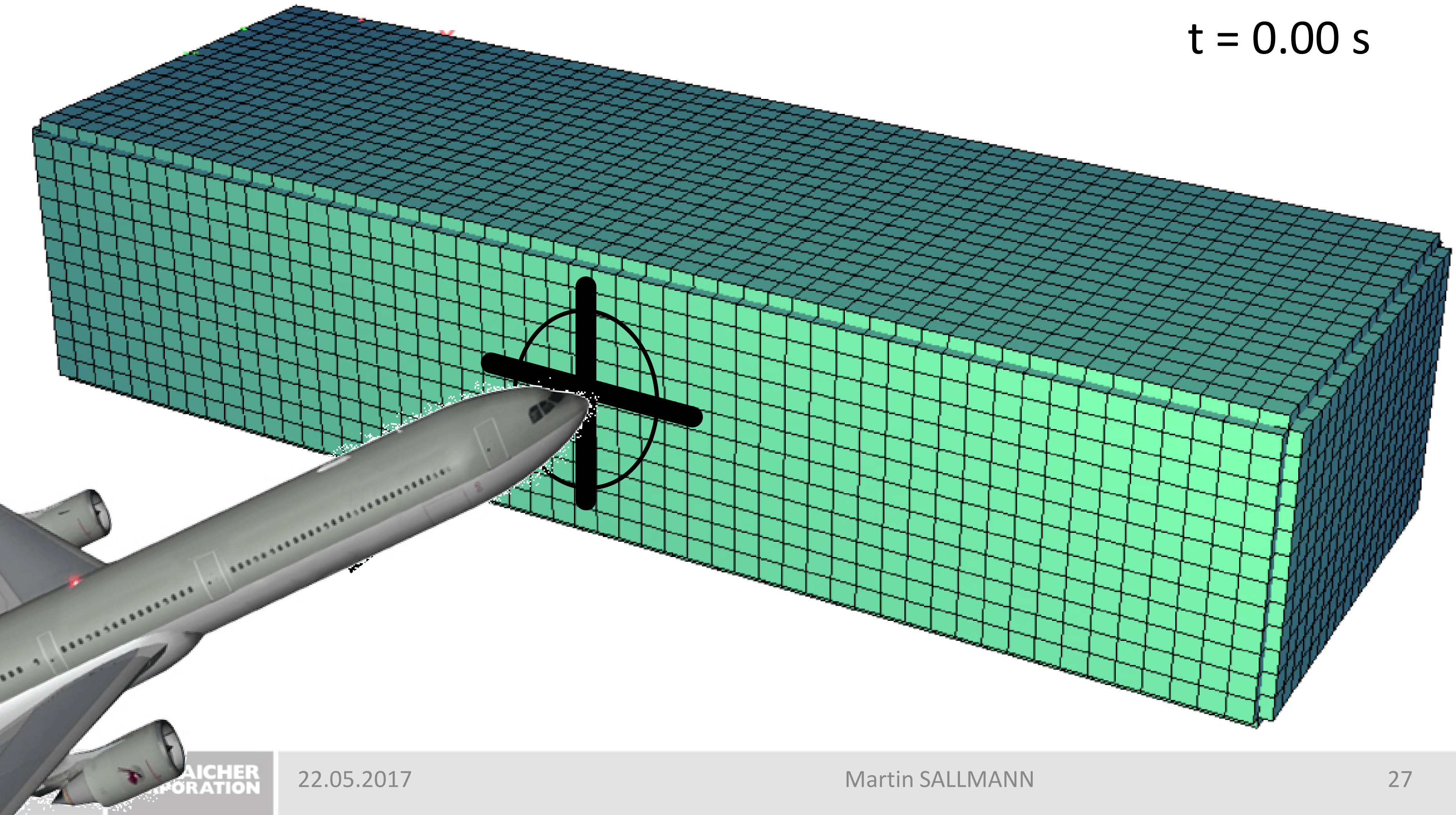


Wall impact F4 Phantom

maximum values of all time steps



Wall impact Airbus A340-600



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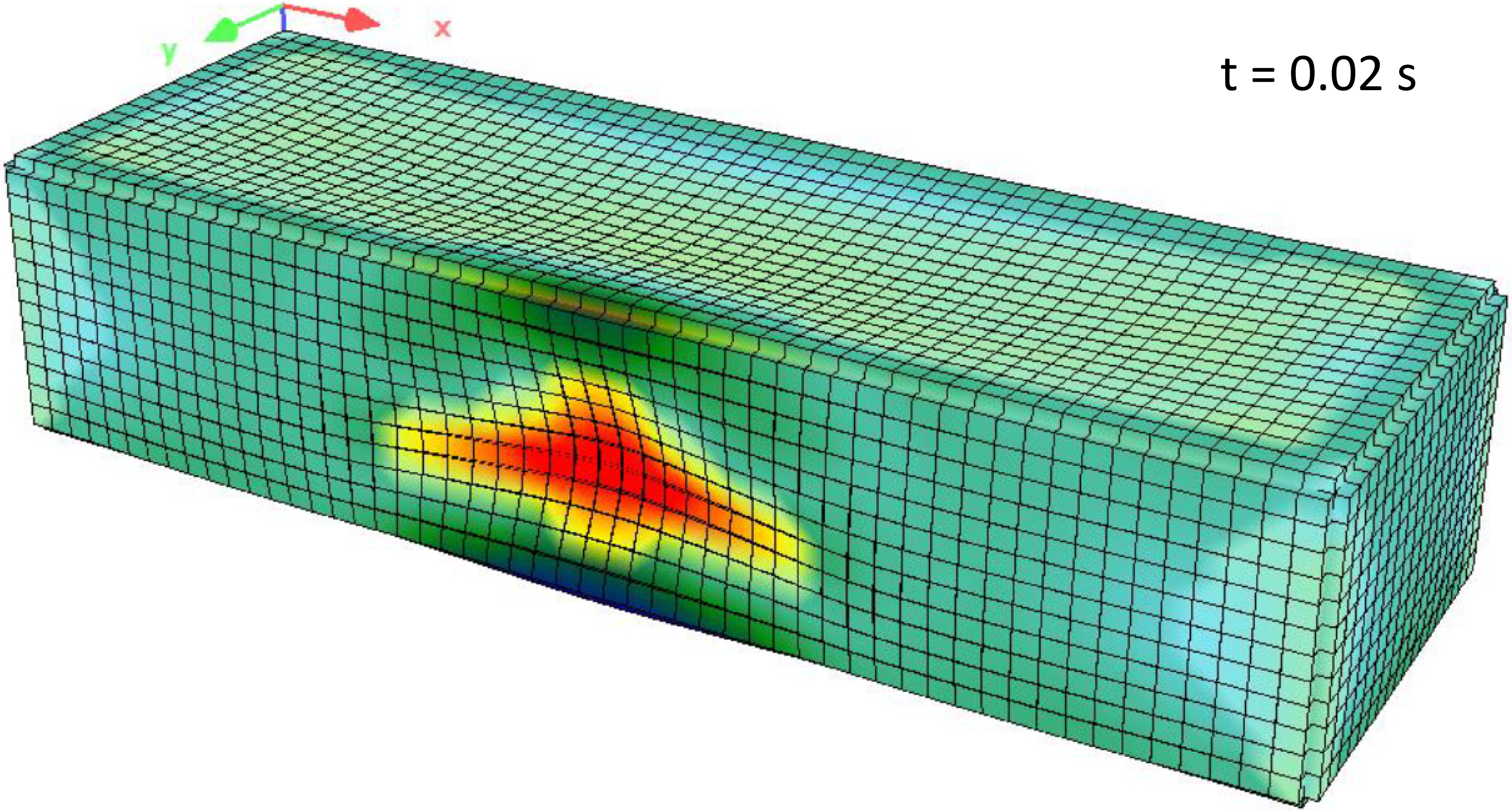
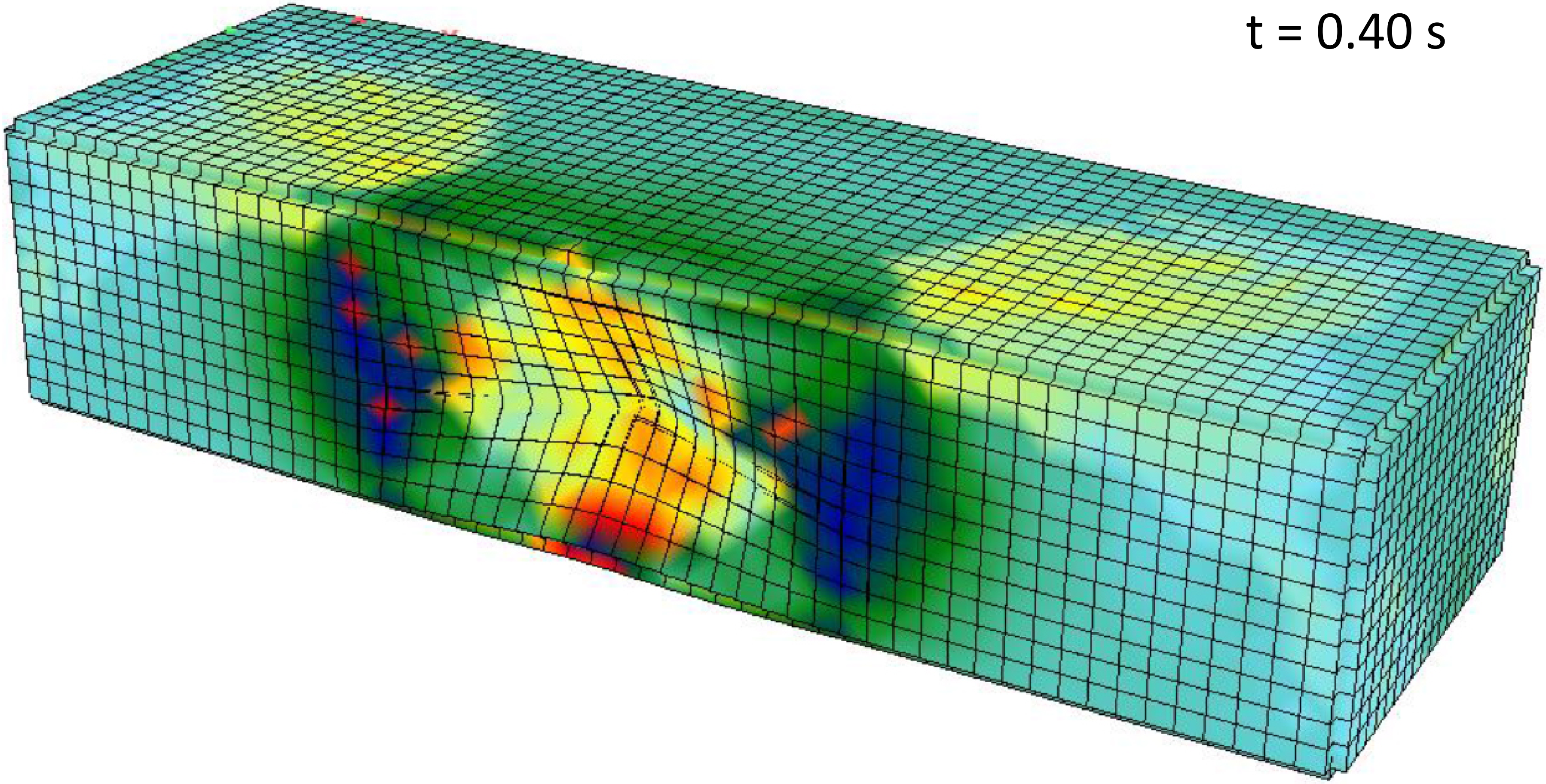
Wall impact Airbus A340-600



t = 0.02 s

Wall impact Airbus A340-600

t = 0.40 s



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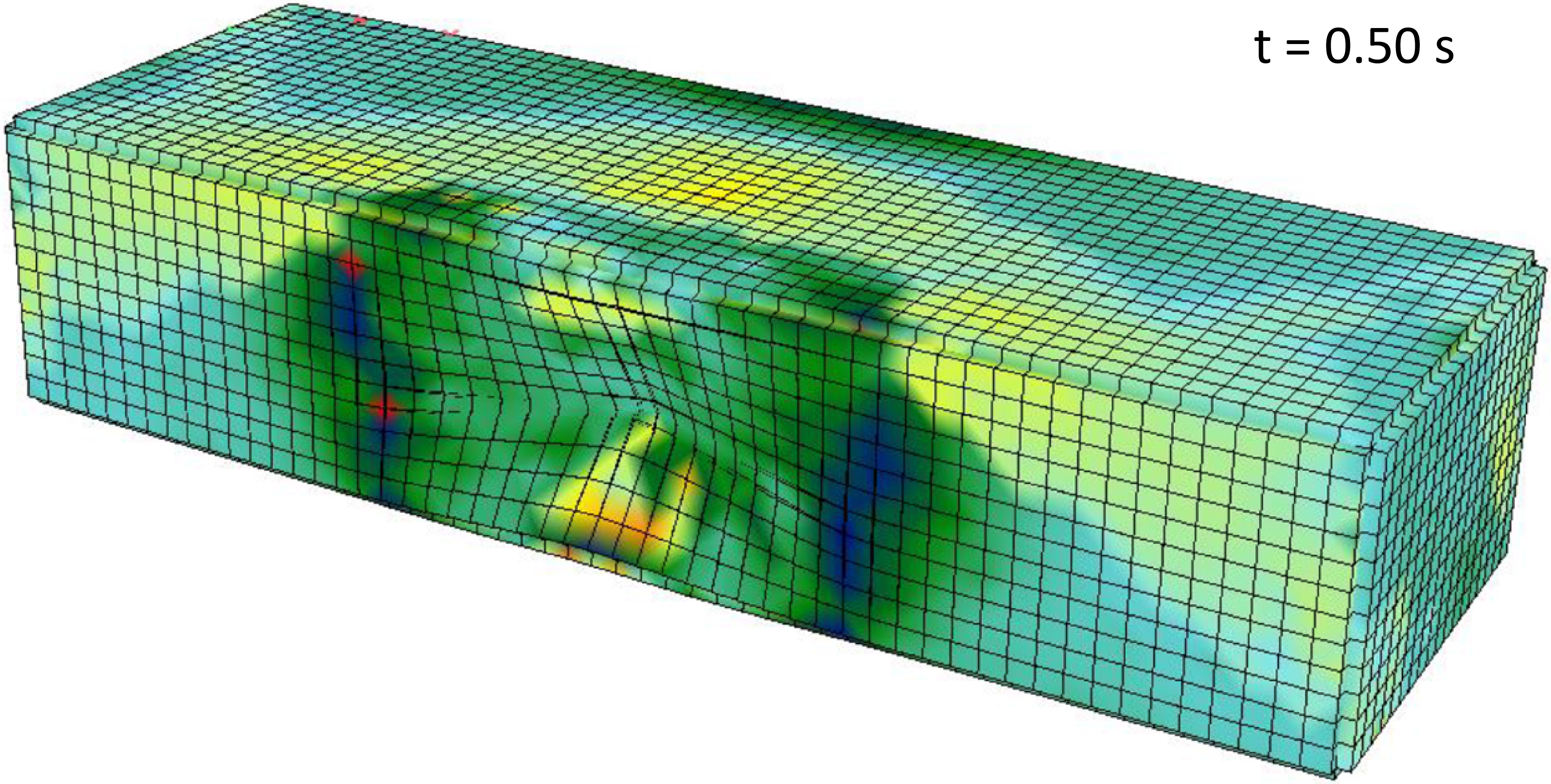
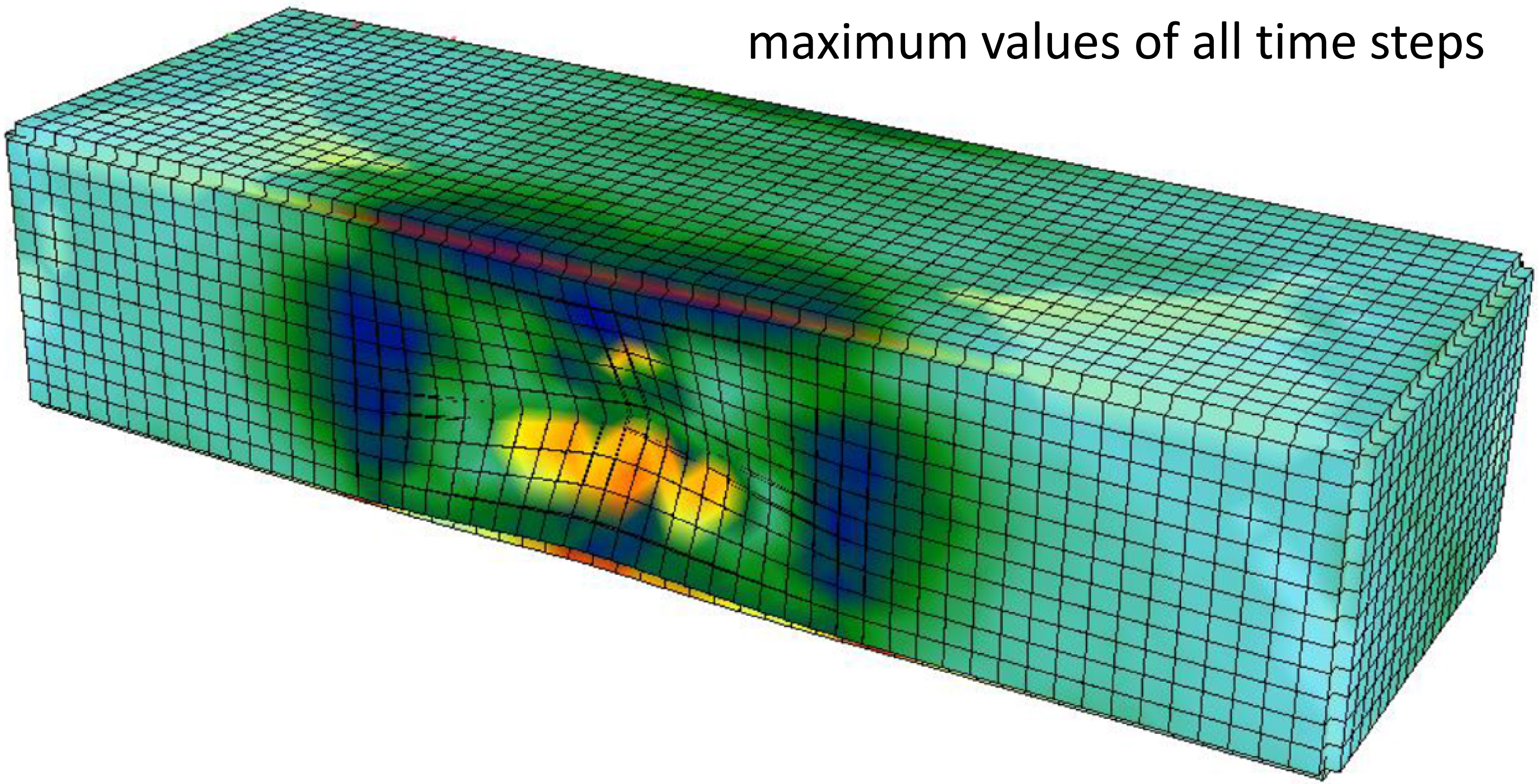
Wall impact Airbus A340-600



t = 0.50 s

Wall impact Airbus A340-600

maximum values of all time steps



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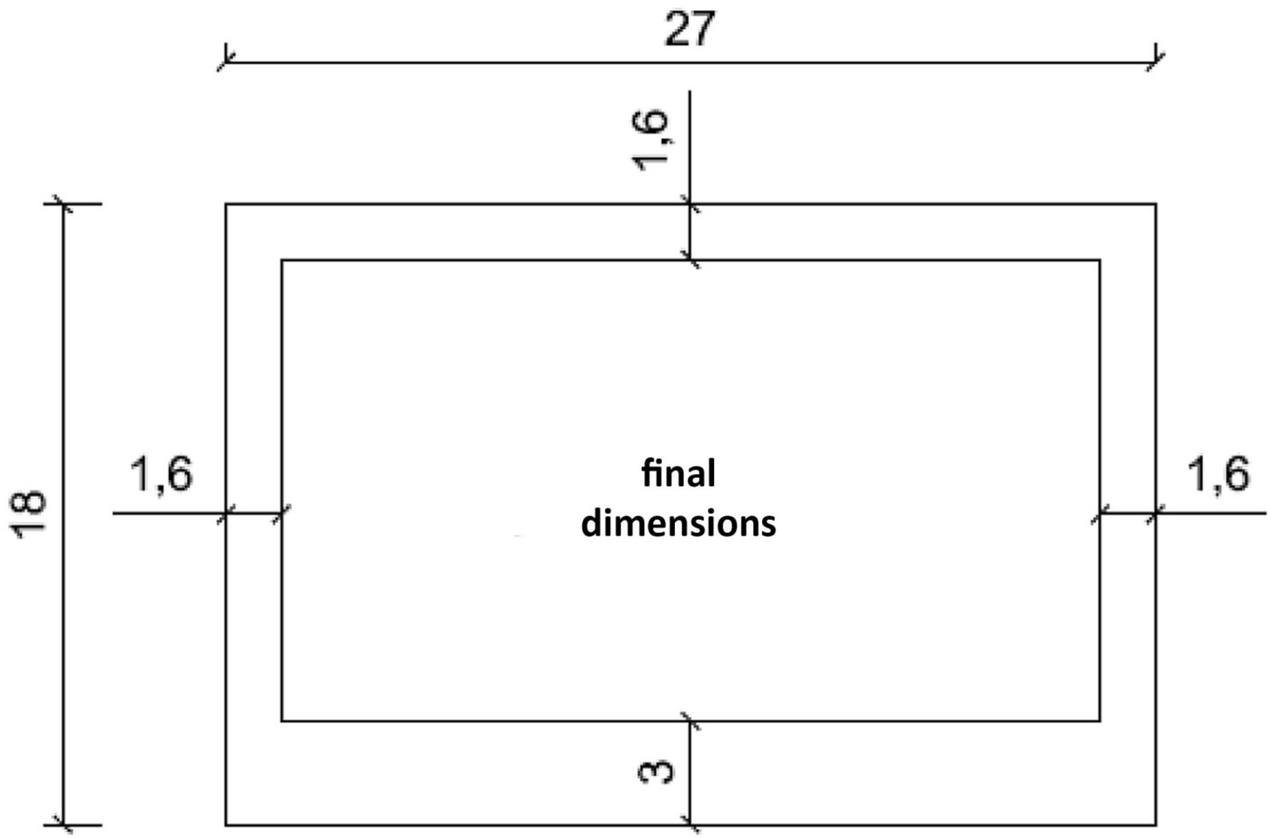
Results from numerical impact analysis

- With a wall thickness of 1.6 m, the building structure is capable to withstand all impact scenarios of an aircraft as described before
- A combination of high-strength steel SAH670/800 (grade 100) and concrete C50/60 is key
- The huge impact forces on the wall caused by a large passenger aircraft require a special foundation to avoid lateral displacement or even tilting of the building (>piling and/or heavier baseplate)

Results from numerical impact analysis



Results from numerical impact analysis

- All examined impact scenarios are extremely unlikely under aeronautical aspects (square for fighter jet / under a ten degree angle for the large passenger aircraft)
- Even under the most unfavorable conditions, the building structure can bear these extreme loads – the building is “failsafe”
- Additional risks for the structure might arise from fuel combustion and should be dealt with accordingly,
  for example by suitable draining devices
- Wall construction offers protection against attack with standard anti-tank-missile (Rocket-Propelled Grenade, “RPG 7”)

Novel solutions

Construction with precast concrete elements

- Based on patent for Modular Standardized Building (MOST), collaboration with AREVA
- Tremendous reduction of construction time
- Savings of up to 38% for the construction time of an emergency diesel building (ZX)

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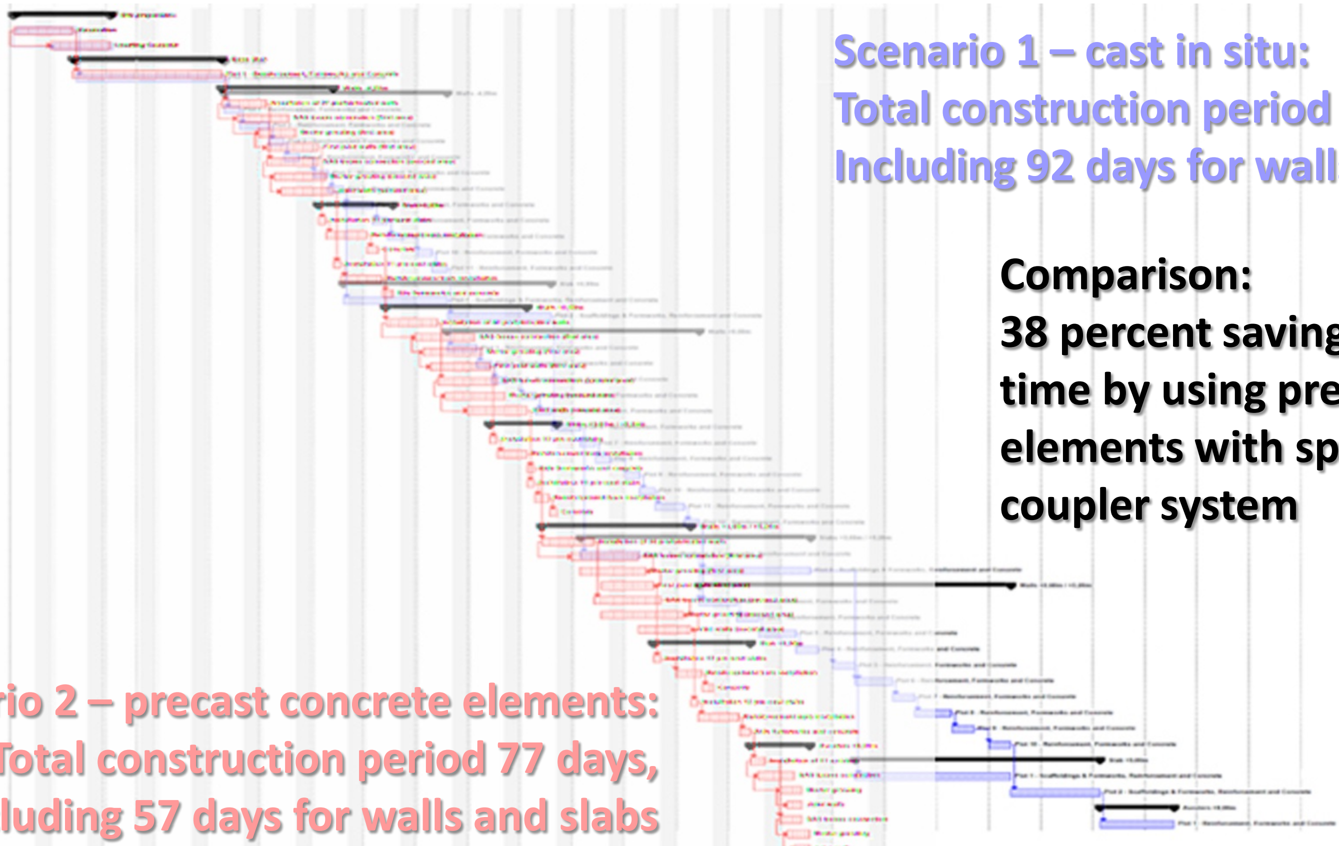
Construction with precast concrete elements, a time-saving alternative

Example: project timeline for the construction of an emergency diesel building (ZX)



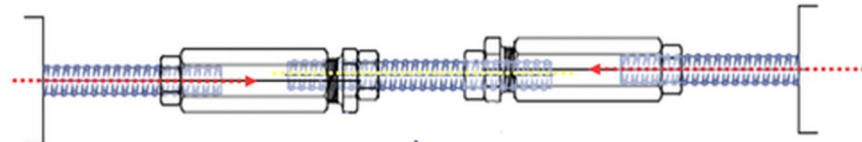
Scenario 1 – cast in situ:
Total construction period 112 days,
Including 92 days for walls and slabs

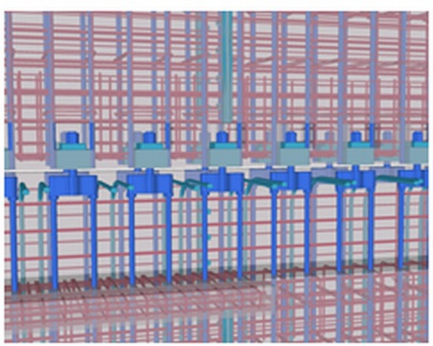
Comparison:
38 percent savings in construction time by using precast concrete elements with special eccentric coupler system

Scenario 2 – precast concrete elements:
Total construction period 77 days,
Including 57 days for walls and slabs

Precast concrete elements – mock-up tests

eccentric coupler system



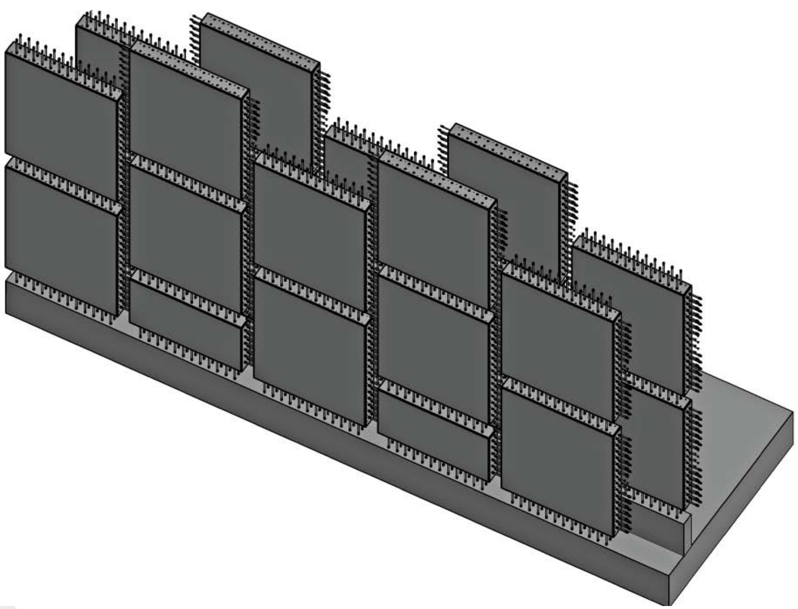


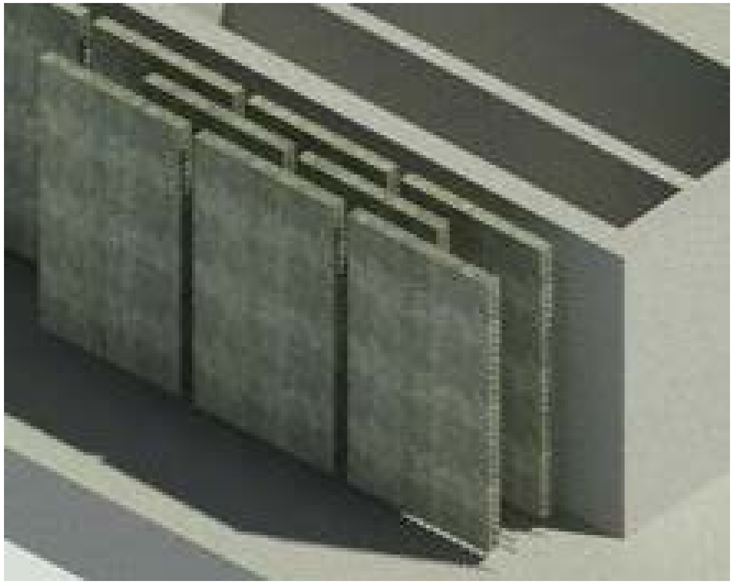
Novel solutions - advantages

- **Reduction of wall thickness** from 1.8 m to 1.6 m without compromising safety of the building structure
- 11% less material by use of high-strength steel SAH670/800 (grade 100) combined with concrete C50/60
- **Use of precast concrete elements**
- 38% savings in construction time for walls and slabs
- Higher quality through sufficient concrete covering

Latest development by Max Aicher Engineering

- New patent pending – multi-layer wall construction with precast concrete elements offers high resistance against future generations of armor-piercing weapons





Disclaimer

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감사합니다.

Thank you for your attention

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