• **Computational Fluid Dynamics (CFD)**
  – Enables the study of the dynamics of things that flow
  – Enable better understanding of qualitative and quantitative physical phenomena
  – Enable to improve engineering designs

• **CFD brings together a number of different disciplines**
  – Fluid dynamics
  – Mathematical theory of partial differential systems
  – Computational geometry
  – Numerical analysis
  – Computer science

• **ANSYS FLUENT is a leading CFD application from ANSYS**
  – Widely used in almost every industry sector and manufactured product
Objectives

- The research was done to provide best practices for ANSYS Fluent
  - MPI library performance comparison
  - Interconnect (Network) performance comparison
  - Scalability

- The presentation will present considerations for higher productivity and efficiency
Cluster Configuration

- **HPE ProLiant DL360 Gen9 128-node (4096-core) “Hercules” cluster**
  - Dual-Socket 16-Core Intel E5-2697A v4 @ 2.60 GHz CPUs
  - Memory: 256GB memory, DDR4 2400 MHz
  - Mellanox ConnectX-5 EDR 100Gb/s InfiniBand Adapters
  - Mellanox Switch-IB2 SB7800 36-port EDR 100Gb/s InfiniBand Switch
  - OS: RHEL 7.4, MLNX_OFED 4.3

- **Dell PowerEdge R730 36-node cluster “Thor” cluster**
  - Dual-Socket 16-Core Intel E5-2697A v4 @ 2.60 GHz CPUs
  - Memory: 256GB memory, DDR4 2400 MHz, Memory Snoop Mode in BIOS sets to Home Snoop
  - InfiniBand EDR Fabric (ConnectX-5 and Switch-IB2 36-ports)
  - Intel Omnipath fabric Operating System and MPI
  - OS: RHEL 7.4, MLNX_OFED 4.3, IFS 10.6.1.0.2
  - Intel MPI 2018.1.163
  - HPC-X 2.1
Fluent Performance (Aircraft Wing 2M and 14M)

Ansys Fluent (aircraft_wing_14m)

Solver Rating

Number of Nodes

4 8 16 32

EDR Infiniband

Ansys Fluent (aircraft_wing_2m)

Solver Rating

EDR Infiniband
Fluent Performance (Combustor 12M and 71M)

**Ansys Fluent**

<table>
<thead>
<tr>
<th>Number of Nodes</th>
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*EDR Infiniband*

**Ansys Fluent**

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*EDR Infiniband*
Fluent Performance (Exhaust 33M, Fluidized_Bed 2M)

**Ansys Fluent** (exhaust_system_33m)

- Number of Nodes: 4, 8, 16, 32
- Solver Rating:
  - EDR Infiniband

**Ansys Fluent** (fluidized_bed_2m)

- Number of Nodes: 4, 8, 16, 32
- Solver Rating:
  - EDR Infiniband
Fluent Performance (Lm6000 16M, Oil Rig 7M)
Fluent Performance (Pump 2M, Rotor 3M)

[Graphs showing Fluent performance with varying number of nodes and solver rating for pump_2m and rotor_3m]
Fluent Performance (Sedan 4M, F1_Racecar 140M)

Ansys Fluent (sedan_4m)

Solver Rating

Number of Nodes

EDR Infiniband

Ansys Fluent (f1_racecar_140m)

Solver Rating

Number of Nodes

EDR Infiniband
Performance – Network Comparison (InfiniBand, OmniPath)

**Ansys Fluent (oil_rig_7m)**

- **Number of Nodes**: 4, 8, 16, 32
- **Solver Rating**: 0, 2000, 4000, 6000, 8000, 10000, 12000, 14000, 16000, 18000
- **Omnipath**
- **EDR Infiniband**

51% improvement at 32 nodes.

**Ansys Fluent (rotor_3m)**

- **Number of Nodes**: 4, 8, 16, 32
- **Solver Rating**: 0, 10000, 20000, 30000, 40000, 50000, 60000, 70000, 80000, 90000
- **Omnipath**
- **EDR Infiniband**

36% improvement at 32 nodes.
The following tests were done on Thor cluster (InfiniBand network), on the same cases using the following MPIs:

- Open MPI
- Intel MPI
- Platform MPI
- HPC-X MPI
Performance – MPI Comparison

Ansys Fluent (ice_2m)

- OpenMPI
- Intel MPI
- Platform MPI
- HPC-X

Ansys Fluent (oil_rig_7m)

- OpenMPI
- Intel MPI
- Platform MPI
- HPC-X
Performance at Scale (Wing, Combustor)

**Ansys Fluent (aircraft_wing_14m)**

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**Ansys Fluent (combustor_12m)**

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<td>12000</td>
</tr>
</tbody>
</table>

- EDR Infiniband
Performance at Scale (Open_Racecar, Lm6000)

Ansys Fluent (open_racecar_280m)

Ansys Fluent (lm6000_16m)

- EDR Infiniband

Solver Rating vs Number of Nodes
Results Analysis

- **Network Comparison**
  - The result tests show the advantages of InfiniBand interconnect

- **MPI Comparison (InfiniBand)**
  - For the several benchmarks, HPC-X exhibits higher performance and better scalability

- **Scalability (InfiniBand)**
  - The Scalability tests show good scalability up to 128 nodes across all benchmarks
Thank You

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