Table 2 - Matrix multiplication compute time time for increasing matrix size (Serial & Parallel with MPI). **Note: You may reduce the size of the matrices to suit your local computing resources**

Number of nodes (Specify 1 if only using your local computer): 1 Number of CPU cores or logical processes: 2 Number of threads used for POSIX/OMP: 2					
Matrix size	500x500	1000x1000	2000x2000	3000x3000	4000x4000
Serial time, Ts (s)	0.49	3.91	33.14	137.18	333.25
Parallel time, Tp - POSIX/OMP (s)	0.26	2.13	18.18	69.81	175.86
MPI communication time (s)	0.00	0.00	0.92	0.20	0.21
Speed Up (Ts/Tp)	1.88	1.83	1.82	1.97	1.90

The theoretical speed up is approximately 1.818.

To calculate the theoretical speedup when using 2 processes compared to the serial version of your matrix multiplication code, we can use Amdahl's Law. This law states that the speedup of a task using multiple processors is limited by the sequential portion of the task.

Amdahl's Law Formula:

$S = 1 / ((1 - P) + P / N)$

Assume that about 90% of the work can be parallelized, then P = 0.9.

$S = 1 / ((1 - 0.9) + 0.9 / 2) \approx 1.818$

The actual speedup values for POSIX/OMP and MPI are generally close to the theoretical speedup (1.818) for smaller matrices (500x500 and 1000x1000). As matrix sizes increase, the actual speedup slightly decreases, especially for the 4000x4000 matrix. The MPI communication time affects the overall speedup and is noticeable in larger matrix sizes. The added communication time leads to a reduced speedup for MPI implementations when compared to POSIX/OMP implementations which do not have communication overhead. For larger matrices (like 4000x4000 and above), the sequential portion of the matrix multiplication especially initialization, cleanup and communication starts to dominate which reduces the potential speedup achievable through parallelization.

```
fit3143-student@fit3143:~/Desktop$ mpirun -np 2 ./task2backup
Matrix Multiplication using MPI - Start

Reading Matrix A - Start
Reading Matrix A - Done
Reading Matrix B - Start
Reading Matrix B - Done
Matrix Multiplication - Start
Matrix Multiplication - Start
Matrix Multiplication - Done
Matrix Multiplication - Done
MPI communication time (s) for rank 1: 0.000782
Write Resultant Matrix C to File - Start
Write Resultant Matrix C to File - Done
Overall time (Including read, multiplication and write)(s): 0.255269
MPI communication time (s): 0.001762
Matrix Multiplication using MPI - Done
fit3143-student@fit3143:~/Desktop$ mpirun -np 2 ./task2backup
Matrix Multiplication using MPI - Start

Reading Matrix A - Start
Reading Matrix A - Done
Reading Matrix B - Start
Reading Matrix B - Done
Matrix Multiplication - Start
Matrix Multiplication - Start
Matrix Multiplication - Done
Matrix Multiplication - Done
MPI communication time (s) for rank 1: 0.014060
Write Resultant Matrix C to File - Start
Write Resultant Matrix C to File - Done
Overall time (Including read, multiplication and write)(s): 2.131062
MPI communication time (s): 0.002247
Matrix Multiplication using MPI - Done
fit3143-student@fit3143:~/Desktop$ mpirun -np 2 ./task2backup
Matrix Multiplication using MPI - Start

Reading Matrix A - Start
Reading Matrix A - Done
Reading Matrix B - Start
Reading Matrix B - Done
Matrix Multiplication - Start
Matrix Multiplication - Start
Matrix Multiplication - Done
Matrix Multiplication - Done
Write Resultant Matrix C to File - Start
MPI communication time (s) for rank 1: 0.046305
Write Resultant Matrix C to File - Done
Overall time (Including read, multiplication and write)(s): 18.175860
MPI communication time (s): 0.915502
Matrix Multiplication using MPI - Done
fit3143-student@fit3143:~/Desktop$ mpirun -np 2 ./task2backup
Matrix Multiplication using MPI - Start

Reading Matrix A - Start
Reading Matrix A - Done
Reading Matrix B - Start
Reading Matrix B - Done
Matrix Multiplication - Start
Matrix Multiplication - Start
Matrix Multiplication - Done
Matrix Multiplication - Done
MPI communication time (s) for rank 1: 0.101079
Write Resultant Matrix C to File - Start
Write Resultant Matrix C to File - Done
Overall time (Including read, multiplication and write)(s): 69.807658
MPI communication time (s): 0.199779
Matrix Multiplication using MPI - Done
fit3143-student@fit3143:~/Desktop$ mpirun -np 2 ./task2backup
Matrix Multiplication using MPI - Start

Reading Matrix A - Start
Reading Matrix A - Done
Reading Matrix B - Start
Reading Matrix B - Done
Matrix Multiplication - Start
Matrix Multiplication - Start
Matrix Multiplication - Done
Matrix Multiplication - Done
MPI communication time (s) for rank 1: 7.029239
Write Resultant Matrix C to File - Start
Write Resultant Matrix C to File - Done
Overall time (Including read, multiplication and write)(s): 175.855027
MPI communication time (s): 0.213772
Matrix Multiplication using MPI - Done
```