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## **SPF: Sparse Polyhedral Framework and Friends**

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# SPF: Sparse Polyhedral Framework and Friends



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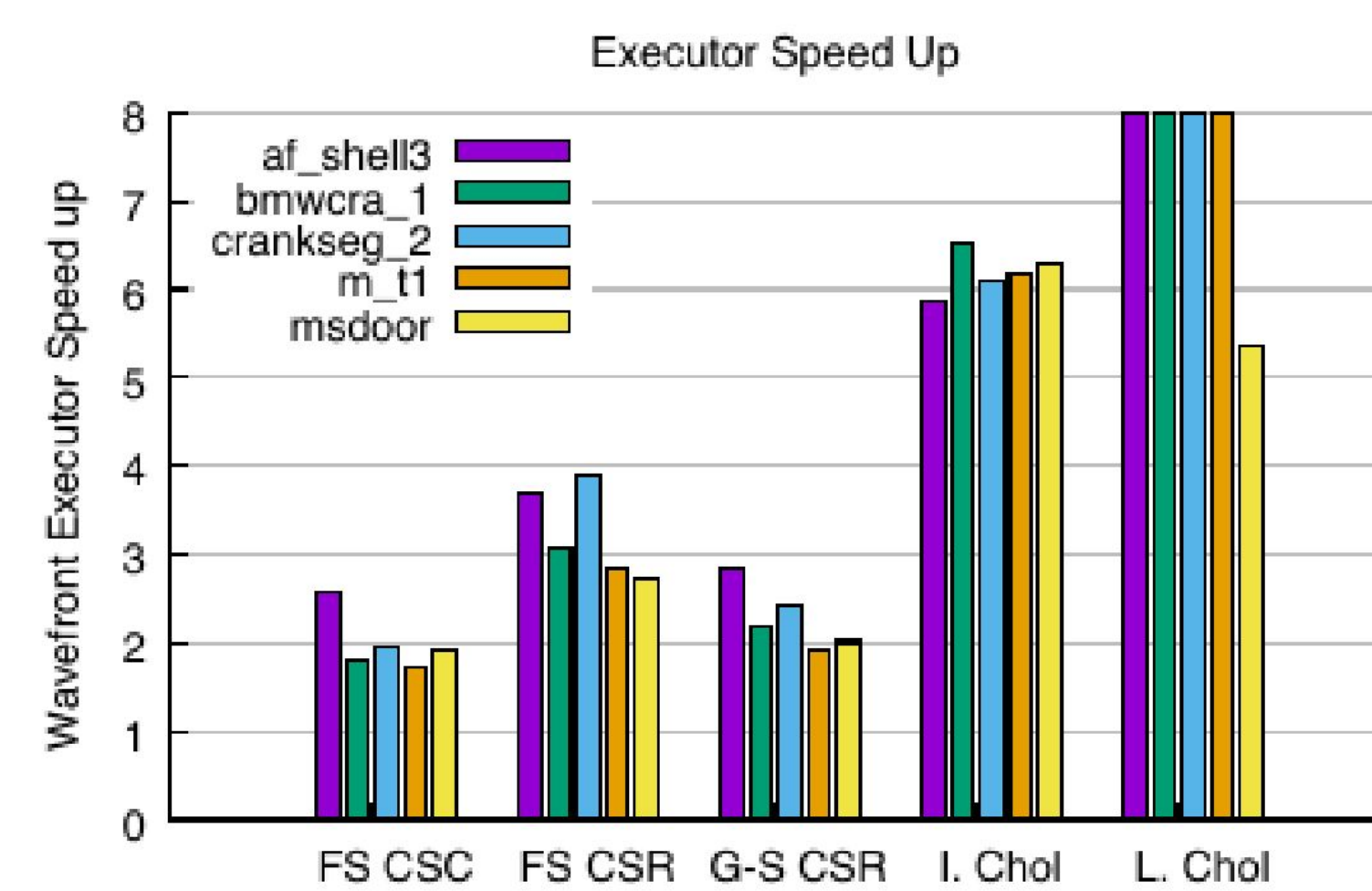


## 1. Problem Statement

- Scientific applications → Computationally intensive → require expensive HPC resources
- Optimizing scientific applications requires a balance of **Performance**, **Productivity**, and **Portability**.

## 2. Motivation

Speedup of executor transformed for wavefront parallelism over library serial code.



- FS - Forward Solve
- GS - Gauss Seidel
- I. Chol - Incomplete Cholesky
- L. Chol - Left Cholesky
- CSR - Compressed Sparse Row format
- CSC - Compressed Sparse Column format

## 3. The Polyhedral Model

- Represents the iteration of each statement of a computation in a loop nest as lattice points in a polyhedron.
- Only supports affine data accesses, and **does not work for sparse computations**.

```
for (i = 1; i <= 3; ++i)
  for (j = 1; j <= 3; ++j)
    S1(i, j)
```

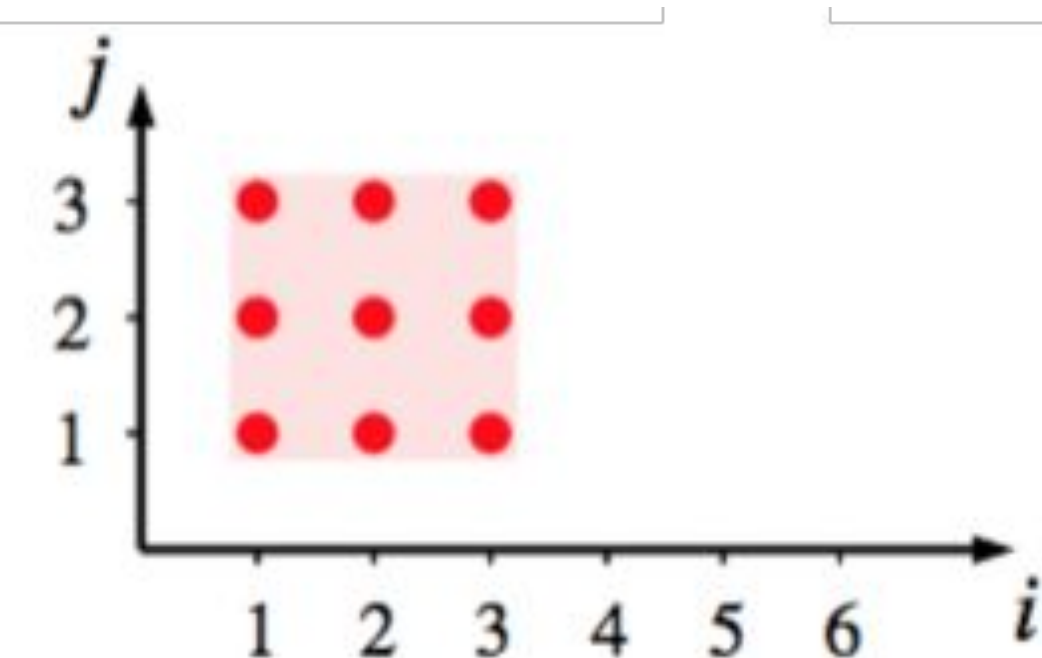
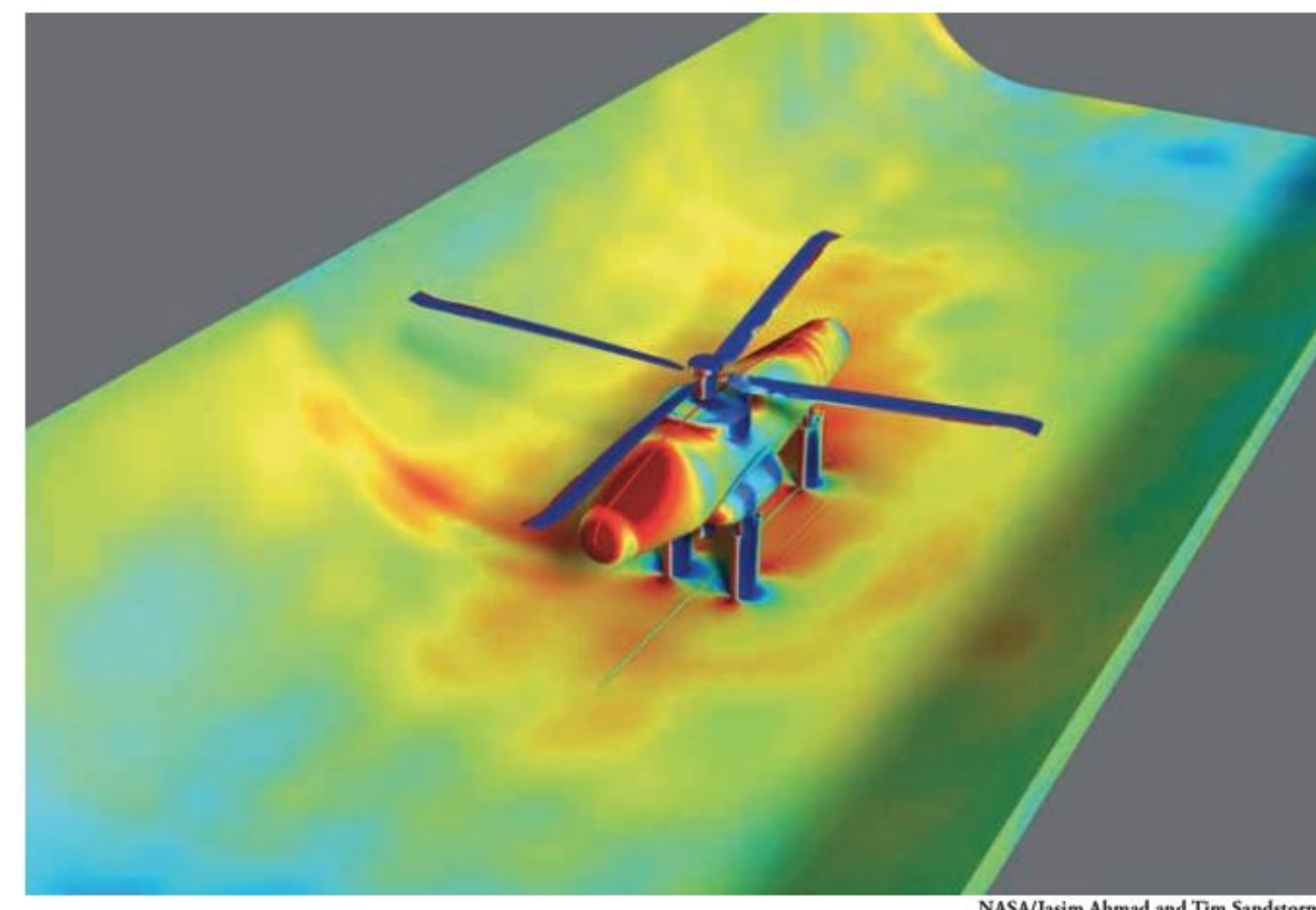
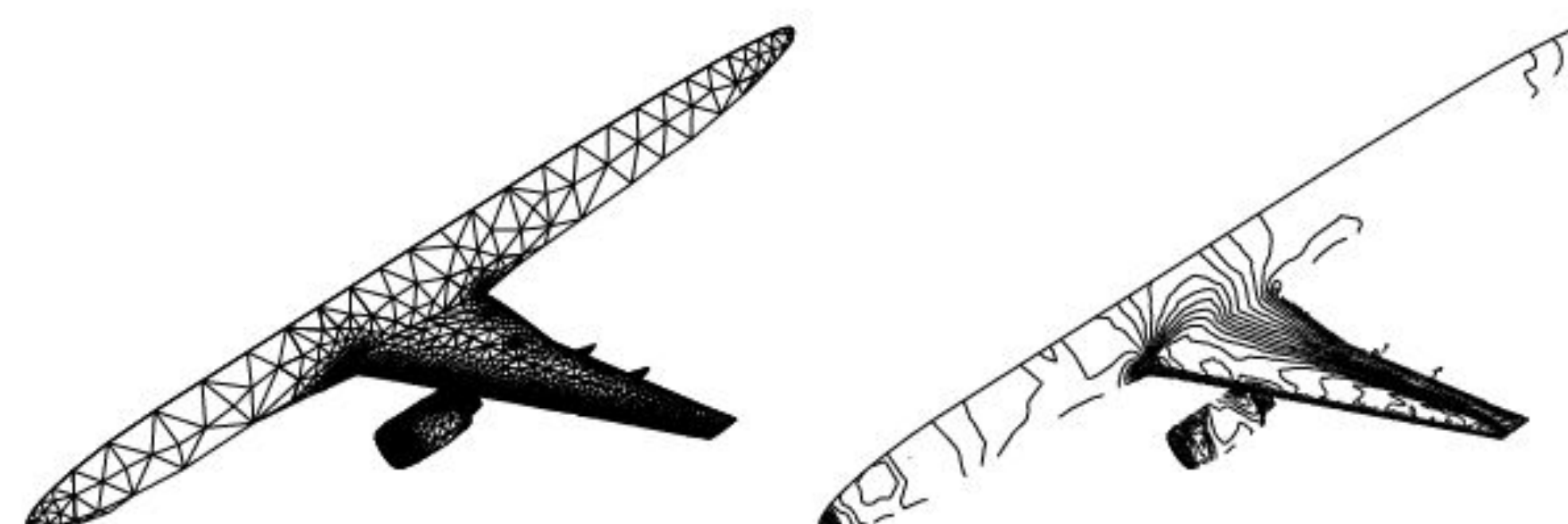


Image source: <http://web.cse.ohio-state.edu/~pouchet2/doc/cic-slides10.pdf>

## 4. Sparse Data



This colorful image is a Computational Fluid Dynamics simulation of a full-scale UH-60A rotor from a Black Hawk helicopter in the giant 40-by-80-Foot Wind Tunnel at NASA Ames Research Center in Moffett Field, California. Colors represent pressure – red is high pressure and blue is low pressure.



A grid used for aircraft computation and computed contours of surface pressure.

source: [https://people.maths.ox.ac.uk/ajlesm/files/parn\\_ctd95.pdf](https://people.maths.ox.ac.uk/ajlesm/files/parn_ctd95.pdf)

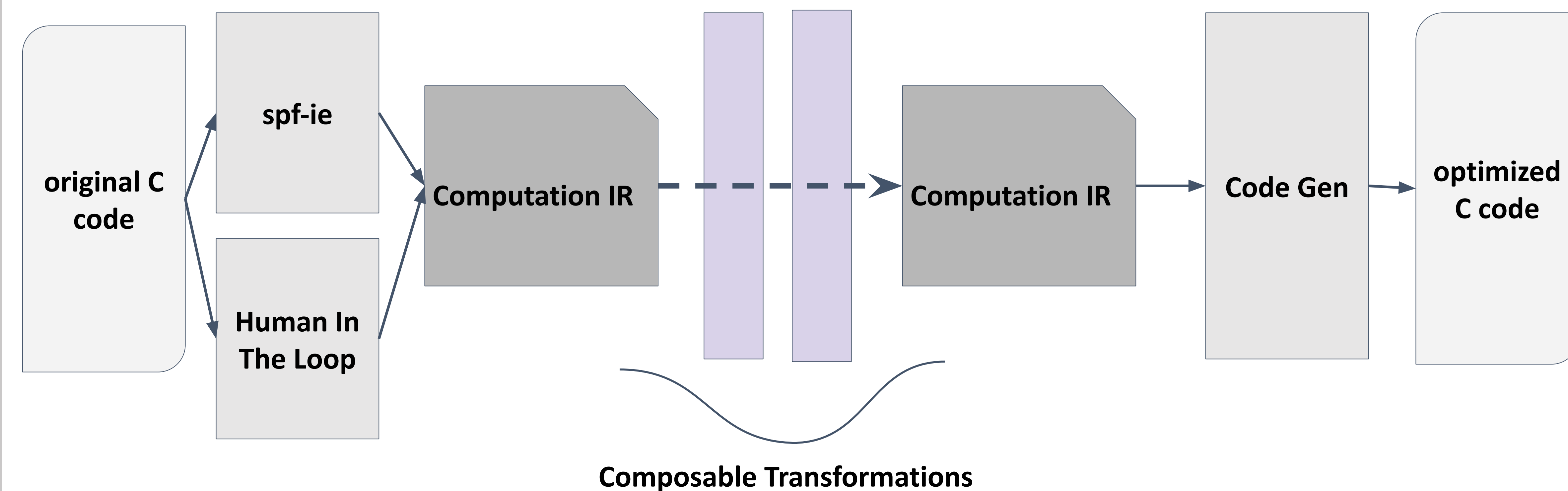
## 5. Sparse Polyhedral Framework (SPF)

- Extends the polyhedral model
- Provides a mathematical framework for representing and transforming irregular computations (uninterpreted functions)
- Suitable for **non-affine** loop bounds present in irregular applications.

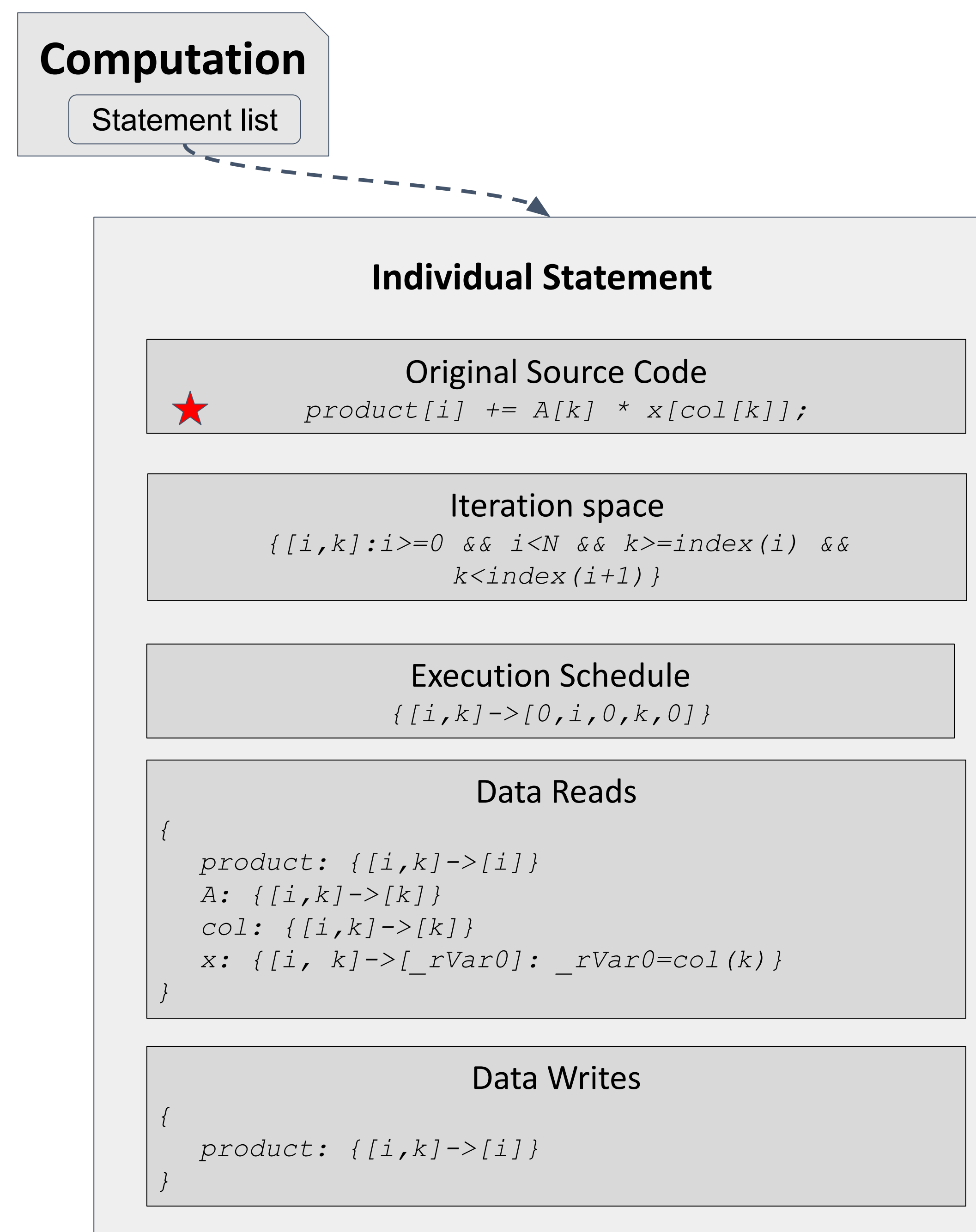
```
for (i = 0; i < N; i++)
  for (k = index[i]; k < index[i + 1]; k++)
    product[i] += A[k] * x[col[k]]; ★
```

$\{[i, k] : i \geq 0 \ \&\& \ i < N \ \&\& \ k \geq \text{index}(i) \ \&\& \ k < \text{index}(i + 1)\}$

## 6. Optimization Overview



## 7. Intermediate Representation



## 8. Future Development

- Currently only have an identity transformation, need to write more
- Algorithmically manipulating data layout to meet execution requirements
- Inlining computations that call others
- Synthesize IR to facilitate conversion from one sparse format to another

## 9. Acknowledgements

Boise State's Research Computing Department. 2017. R2: Dell HPC Intel E5v4 (High Performance Computing Cluster). Boise, ID: Boise State University. DOI: [10.18122/B2S41H](https://doi.org/10.18122/B2S41H)

## 10. Collaborators

