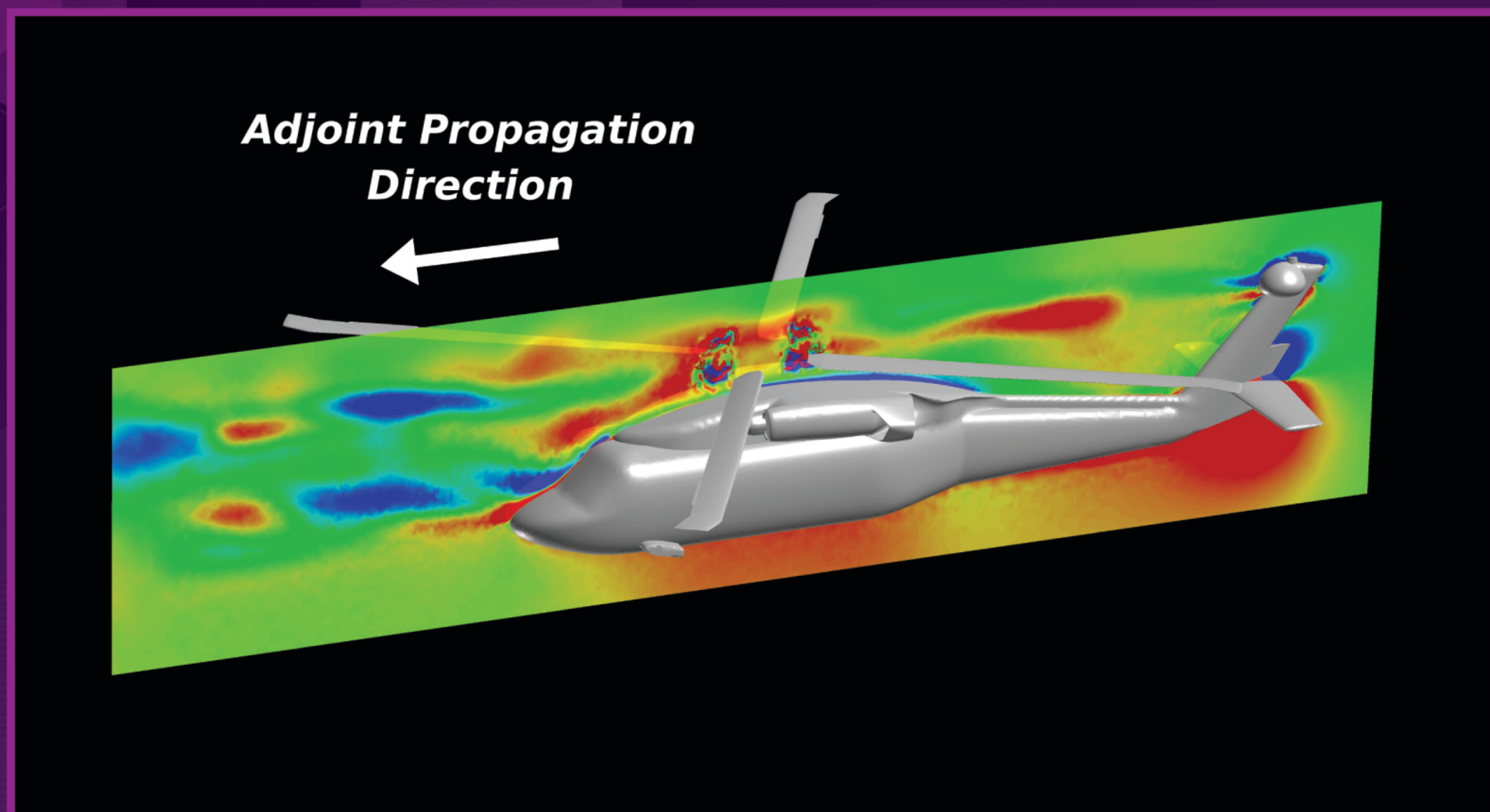
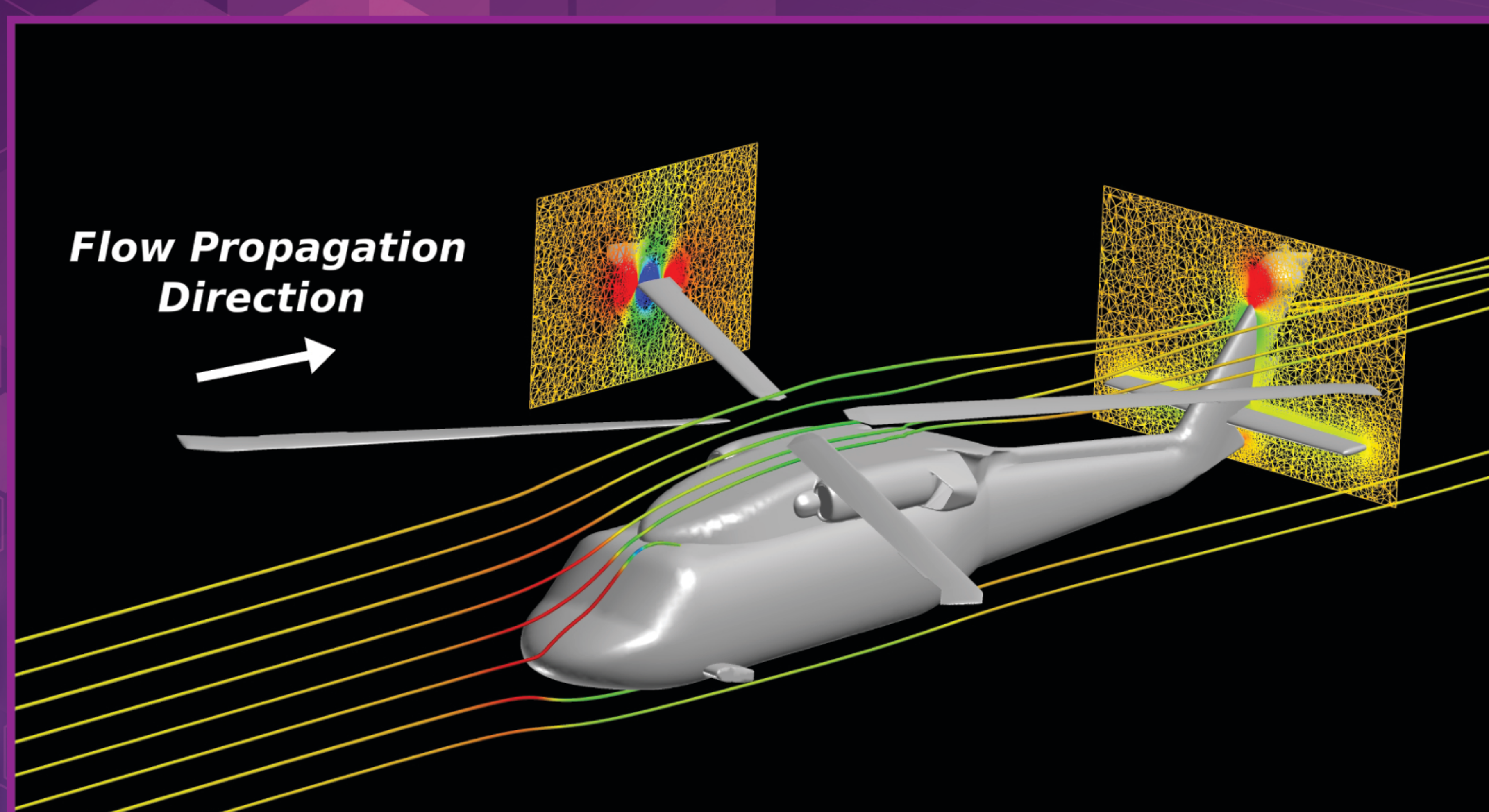
Adjoint-Based Design for Complex Aerospace Configurations



Upstream propagation of adjoint solution for a UH-60 Black Hawk helicopter in forward flight. Contours indicate where the lift is sensitive to perturbations in both space and time. *Eric Nielsen, NASA/Langley; Boris Diskin, National Institute of Aerospace*



Downstream propagation of flow solution for a UH-60 Black Hawk helicopter in forward flight. *Eric Nielsen, NASA/Langley; Boris Diskin, National Institute of Aerospace*

We have developed adjoint-based methods to enable formal, constrained design optimization of complex aerospace configurations experiencing unsteady turbulent flows, and requiring dynamic/deforming geometries and high-fidelity physical models. Adjoint-based methods implemented on massively parallel computers allow design engineers to formally tackle a broad array of complex optimization problems across the speed range, which would otherwise remain computationally intractable.

- The adjoint solution integrates the linearized governing equations backward in time to determine numerical sensitivities to all simulation inputs
- Our implementation supports steady and unsteady compressible and incompressible turbulent flows on dynamic, deforming overset grids with general parent-child body motions
- A highly efficient asynchronous parallel I/O paradigm manages terabytes of data necessary to integrate the simulation backward in time
- The adjoint method has been implemented in the NASA FUN3D flow solver

This approach has been successfully demonstrated on a broad range of realistic design problems, including rotorcraft geometries, fighter jets, biologically inspired micro-air vehicle configurations, active flow control systems, and wind energy devices. It also provides a rigorous foundation, valuable insight, and an effective tool for error estimation, mesh adaptation, and uncertainty quantification for such problems.

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