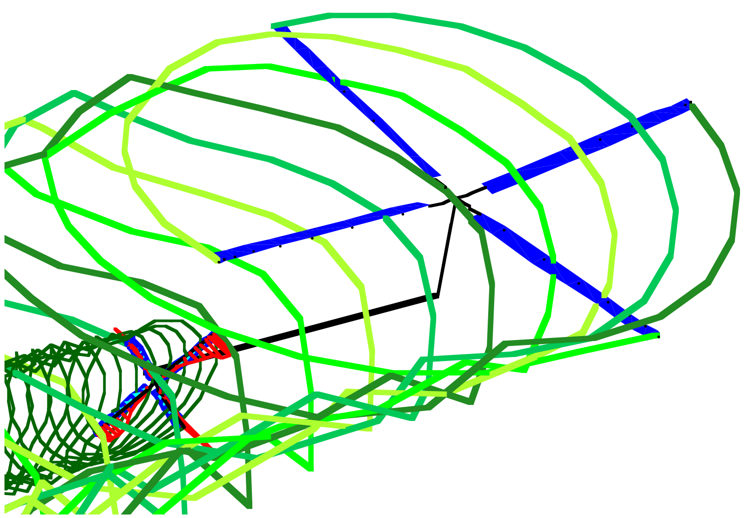
CAMRAD II

COMPREHENSIVE ANALYTICAL MODEL OF ROTORCRAFT AERODYNAMICS AND DYNAMICS



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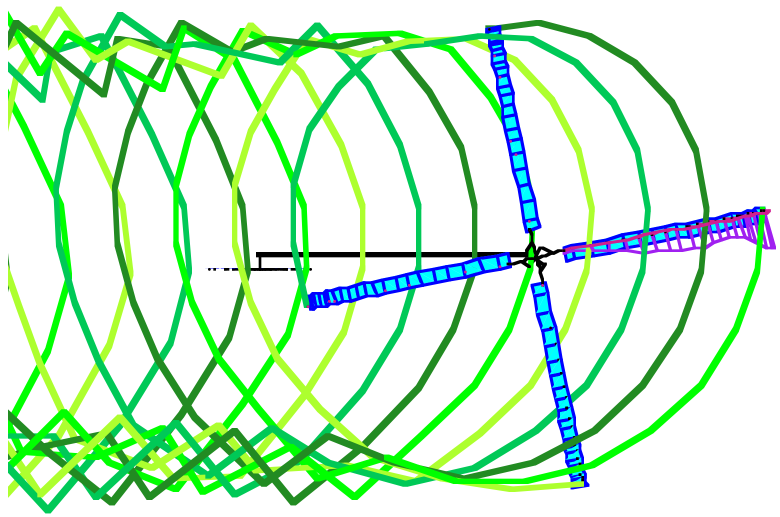
CAMRAD II IS AN AEROMECHANICAL ANALYSIS OF HELICOPTERS AND ROTORCRAFT

INCORPORATING ADVANCED TECHNOLOGY
- multibody dynamics
  - nonlinear finite elements
    - rotorcraft aerodynamics and wakes



FOR DESIGN, TESTING, AND EVALUATION OF ROTORS AND ROTORCRAFT

- AT ALL STAGES — RESEARCH, CONCEPTUAL DESIGN, DETAILED DESIGN, DEVELOPMENT

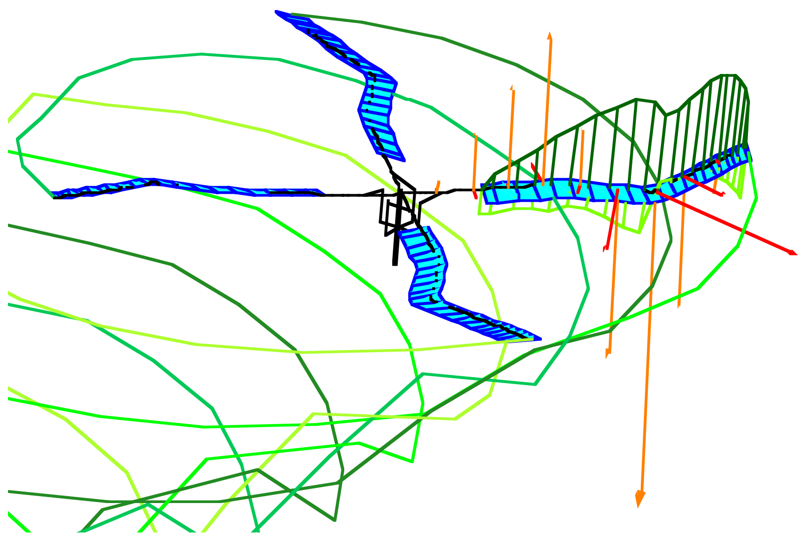
  - CALCULATES PERFORMANCE, LOADS, VIBRATION, RESPONSE, STABILITY

- CONSISTENT, BALANCED, YET HIGH LEVEL OF TECHNOLOGY IN SINGLE COMPUTER PROGRAM

FOR WIDE RANGE OF PROBLEMS AND WIDE CLASS OF ROTORCRAFT

CAMRAD II DESIGNED FOR FLEXIBILITY IN MODEL OF DYNAMIC AND AERODYNAMIC CONFIGURATION

FLEXIBILITY AND GENERALITY OF
CONFIGURATION ACHIEVED BY
ASSEMBLING STANDARD COMPONENTS
WITH STANDARD INTERFACES,
AND SOLVING SYSTEM
USING STANDARD PROCEDURES



SO CAMRAD II CAN MODEL TRUE GEOMETRY
OF ROTORCRAFT

multiple load paths
- such as swashplate and control system, lag dampers, bearingless rotor

vibration control devices
- such as pendulum absorbers or active control

arbitrary elastic axis and arbitrary hinge order

drooped and swept tips, dissimilar blades

RANGE OF MODELLING OPTIONS MAKES
CAMRAD II A PRACTICAL ENGINEERING TOOL

can balance efficiency and accuracy for a particular problem

CONFIGURATIONS

FOR EASE OF USE, SHELL PROVIDED TO BUILD TYPICAL ROTORCRAFT AND ROTOR MODELS, AND SOLVE TYPICAL PROBLEMS

core input always gives complete flexibility to define and revise the model

ONE-ROTOR OR TWO-ROTOR HELICOPTER OR TILTROTOR

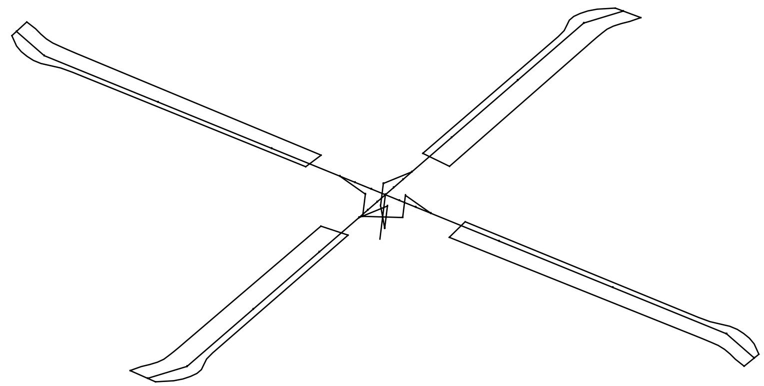
- main-rotor / tail-rotor helicopter
- tandem and coaxial helicopters
- tilting proprotor aircraft

GENERAL MULTI-ROTOR AIRCRAFT

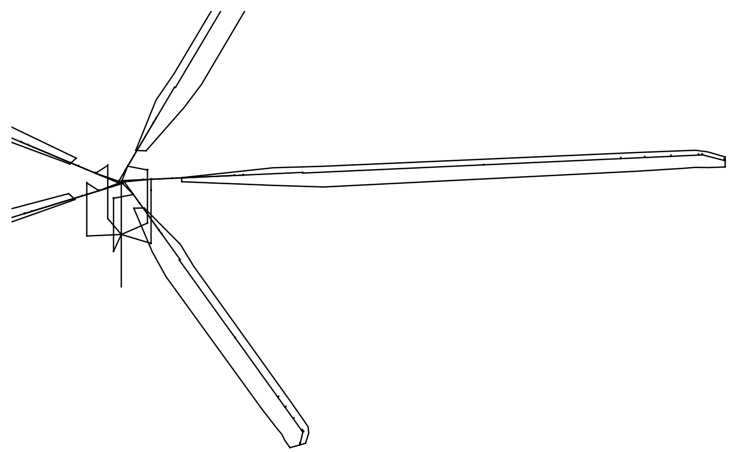
WIND TUNNEL OR FREE FLIGHT OPERATING CONDITIONS

ARTICULATED, TEETERING, GIMBALLED, HINGELESS, OR BEARINGLESS HUB, WITH ARBITRARY NUMBER OF BLADES

Advanced Technology Rotor Systems



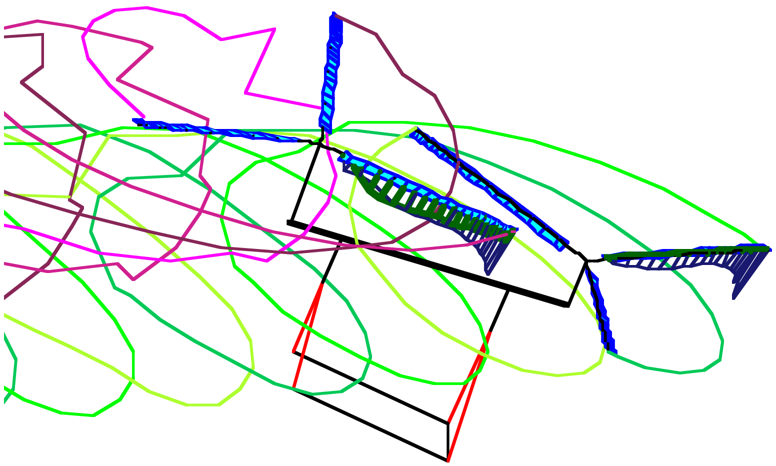
Bearingless Rotor with Swept-Tip Blades



CONFIGURATIONS

SWASHPLATE AND PITCH LINK MODEL
WITH TRUE LOAD PATH
    or rotor control introduced at pitch bearing
    (simpler, approximate model)

IDENTICAL, EQUALLY SPACED BLADES
or
DISSIMILAR, NON-EQUALLY-SPACED BLADES



NORMAL MODES REPRESENTATION OF
AIRFRAME ELASTIC MOTION
and
TRANSMISSION COMPONENTS FOR DRIVE
TRAIN MODEL (only deal with torques)
or
BUILD FUSELAGE AND DRIVE TRAIN FROM
RIGID BODIES AND BEAM ELEMENTS

SLUNG LOADS

NONROTATING WINGS

WIND TURBINES

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CAMRAD II ANALYSIS TASKS

TRIM TASK

FIND EQUILIBRIUM SOLUTION FOR STEADY STATE OPERATING CONDITION

- arbitrary trim targets and controls
- harmonic or time-finite-element solution
- high resolution post-trim solution for coupling with external aeroacoustic analysis

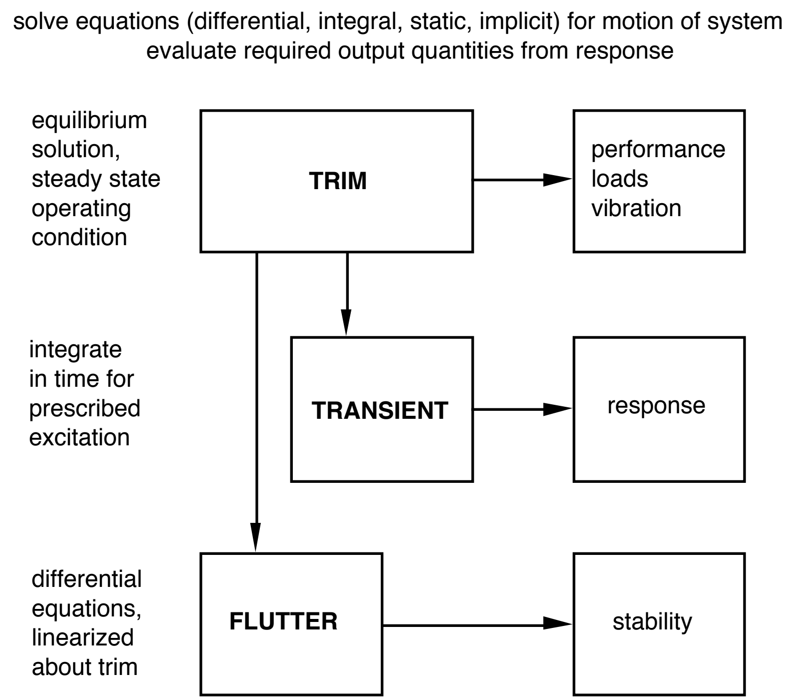
TRANSIENT TASK

INTEGRATE EQUATIONS IN TIME FOR PRESCRIBED EXCITATION

FLUTTER TASK

ANALYZE DIFFERENTIAL EQUATIONS, LINEARIZED ABOUT TRIM SOLUTION

- constant coefficients or Floquet theory
- eigenanalysis, time history solution, frequency response



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CAMRAD II STRUCTURAL DYNAMICS

MULTIBODY DYNAMICS / FINITE ELEMENT BASIS FOR STRUCTURAL DYNAMICS, WITH OPTIONAL MODAL REDUCTION

EXACT KINEMATICS AND EQUATIONS OF MOTION FOR ALL RIGID BODY MOTION, ALL JOINT MOTION, AND ALL INTERFACES

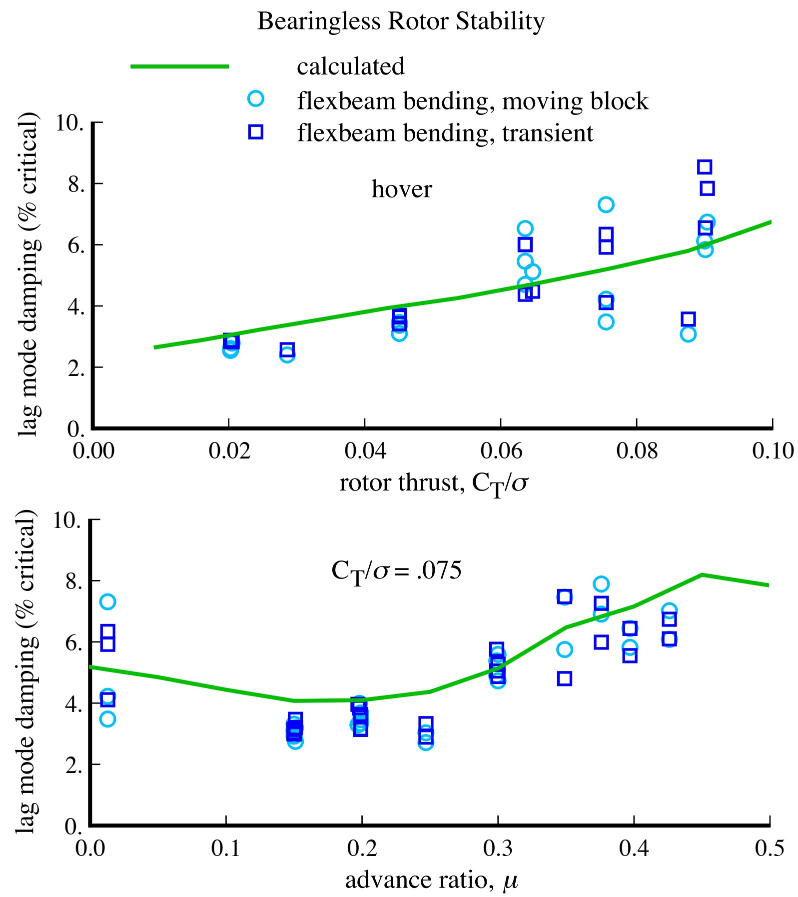
LARGE MOTION

GENERAL SPRING / DAMPER / ACTUATOR MODEL CAN BE USED AT ANY JOINT

BEAM ELEMENT CAN BE USED ANYWHERE IN SYSTEM, NOT JUST FOR ROTOR BLADES

STRUCTURAL DYNAMIC COMPONENTS AVAILABLE:

- rigid body
- linear normal modes (for fuselage)
- transmission (for drive train)
- rod/cable
- beam



BEAM COMPONENT

EXACT RIGID BODY AND JOINT MOTION

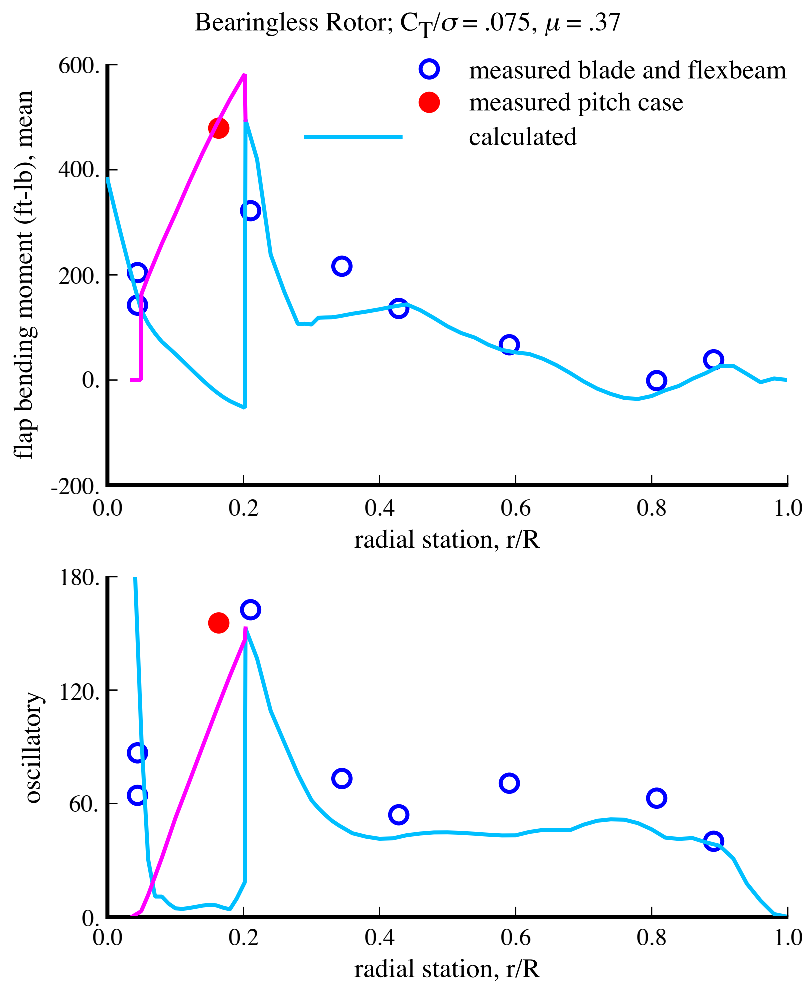
ARBITRARY BEAM AXIS OR ELASTIC AXIS
straight within beam element

OPTIONS FOR KINEMATICS OF BEAM ELASTIC MOTION:

2nd order (Hodges and Dowell)
or
almost exact (extension/torsion from bending still 2nd order)
or
geometrically exact (still small strain)

OPTIONS FOR BEAM STRUCTURAL MODEL:

isotropic beam with elastic axis
or
anisotropic or composite material, without assumption that beam axis is elastic axis



CAMRAD II AERODYNAMICS

ROTORCRAFT AERODYNAMICS MODEL
BASED ON LIFTING LINE THEORY,

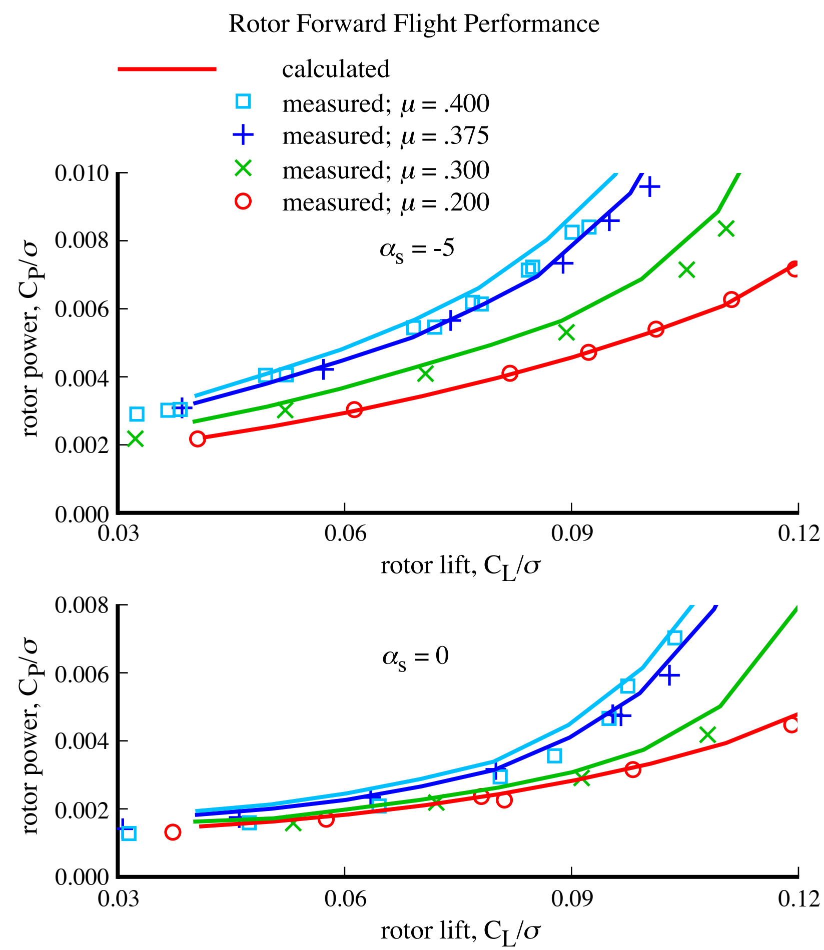
WITH SOPHISTICATED WAKE ANALYSIS
TO CALCULATE NONUNIFORM
INDUCED VELOCITIES,

USING RIGID, PRESCRIBED, OR
FREE WAKE GEOMETRY

WINGS AND WAKES CAN BE USED
ANYWHERE IN SYSTEM, NOT JUST FOR
ROTOR BLADES

AERODYNAMIC COMPONENTS AVAILABLE:

- rigid airframe aerodynamics
- airframe flow field
- lifting line wing
- wing inflow, rotor inflow
- wing wake
- wing wake geometry, rotor wake geometry
- helicopter tail boom
- computational fluid dynamics



AERODYNAMIC COMPONENTS

AIRFRAME AERODYNAMICS
  coefficients from equations or from tables

WIND
  including ground boundary layer

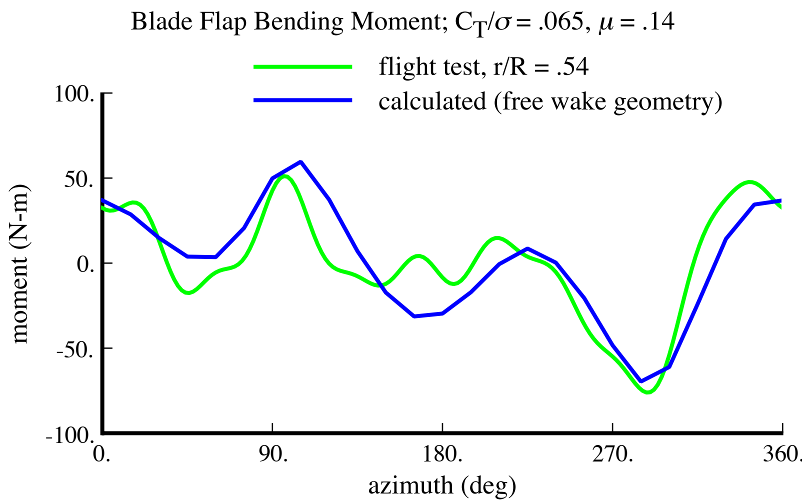
GUST
  uniform, convected, and tabular models

ROTOR INFLOW
  momentum theory with corrections

  ducted fan, including fan-in-fin tail rotor

HELICOPTER TAIL BOOM
  circulation-controlled tail boom with reaction jet

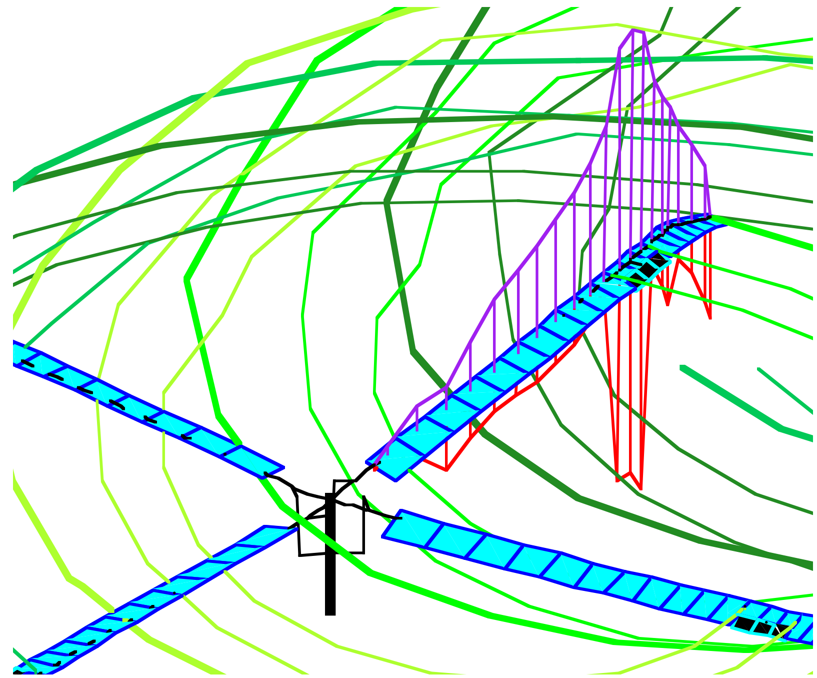
COMPUTATIONAL FLUID DYNAMICS
  interface with user-supplied cfd code



WING COMPONENT

BASED ON SECOND-ORDER LIFTING-LINE THEORY

AIRFOIL TABLES WITH CORRECTIONS
including static stall delay factors



ARBITRARY QUARTER-CHORD LOCUS
(DROOP AND SWEEP ALONG WING AXIS)
AND TWIST

UNSTEADY AERODYNAMICS MODELS:
incompressible, ONERA EDLIN,
Leishman-Beddoes

DYNAMIC STALL MODELS:
Johnson, Boeing, Leishman-Beddoes
ONERA EDLIN, ONERA BH

TRAILING EDGE FLAP
including unsteady loads

WAKE AND WAKE GEOMETRY COMPONENTS

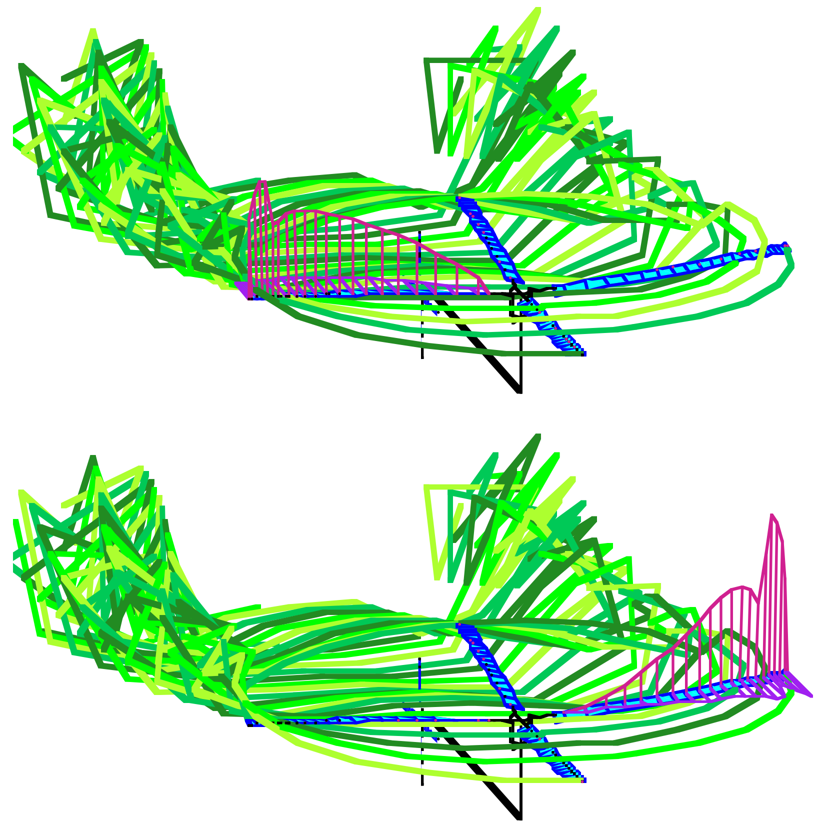
MOMENTUM THEORY,
RIGID / PRESCRIBED WAKE GEOMETRY,
OR FREE WAKE GEOMETRY
   as appropriate to problem

INDUCED-VELOCITY CALCULATION
   single-peak and dual-peak (negative tip loading) rollup models

   tip vortex entrainment and inboard sheet stretching model

   tip vortex core models

   ground plane influence

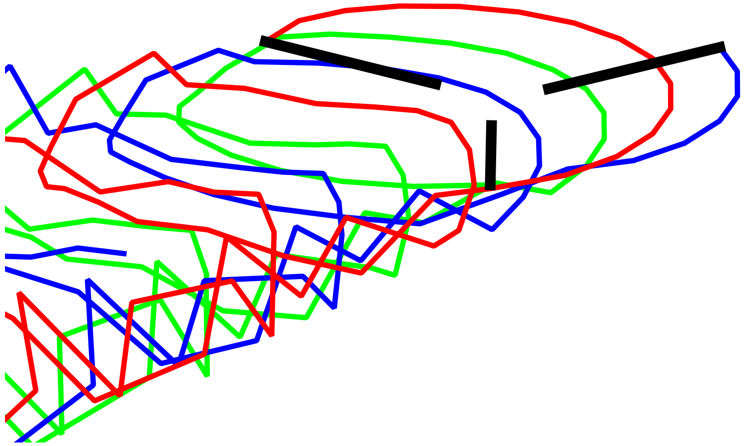


FREE WAKE GEOMETRY
   forward flight, low speed, and hover
   multiple rotors and wings
   distortion of all vortex structures
   trim and transient tasks

   airframe flow field influence
   ground plane influence

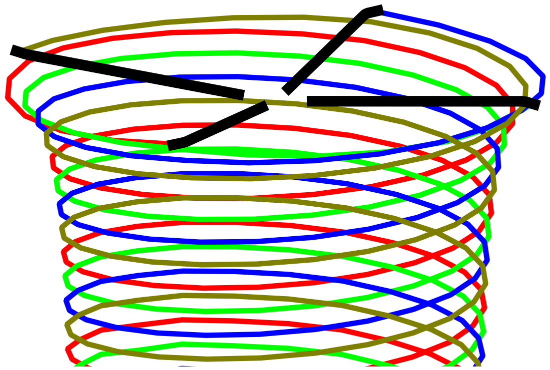
OTHER CAMRAD II COMPONENTS

RIGID WING
combination of rigid body and lifting-line wing components, trading generality for efficiency



WING, ROTOR, AND ROTORCRAFT PERFORMANCE
calculate standard performance measures

REFERENCE FRAME
access to frame motion, and transformation and addition of vectors



FILTER
periodic time history:
- operation such as mean, half-peak-to-peak, harmonic, or derivative

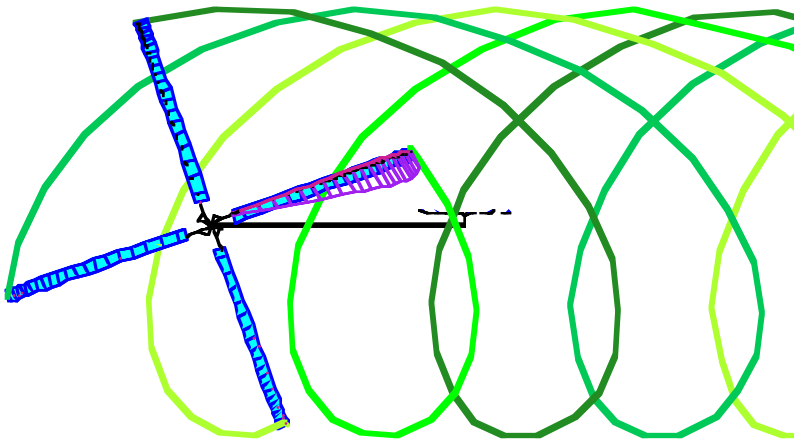
general time history:
- low pass filter or harmonic analysis

REFERENCE PLANE
for rotor tip-path plane motion

OTHER CAMRAD II COMPONENTS

DIFFERENTIAL EQUATION
static (scalar addition), first-order, or second-order linear differential equations

TRANSFER FUNCTION
linear differential equation (from poles and zeros)



PROGRAMMABLE
incorporate user-programmed routines (based on differential equation component)

FOURIER SERIES
calculate time history from harmonics

PRESCRIBED CONTROL
generate prescribed input for transient task

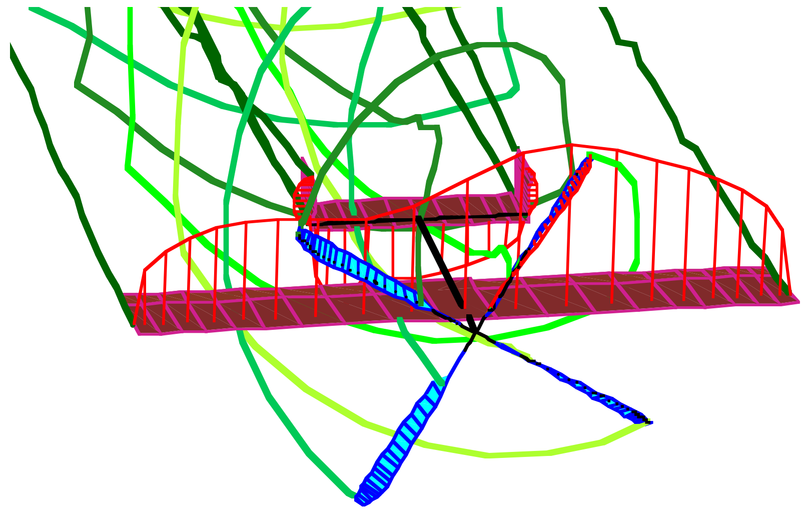
PLUGIN
shell plugins and plugin components; developed, distributed, and supported by other companies

CAMRAD II DEVELOPED BY JOHNSON AERONAUTICS

THEORY AND SOFTWARE DEVELOPED BY
WAYNE JOHNSON

DR. JOHNSON HAS OVER 30 YEARS EXPERIENCE ANALYZING ROTORCRAFT AND DEVELOPING SOFTWARE, AT JOHNSON AERONAUTICS, U.S. ARMY, AND NASA

AUTHOR OF WIDELY USED TEXTBOOK "HELICOPTER THEORY"



FIRST RELEASE OF CAMRAD II WAS IN 1993

TRAINING AND SOFTWARE APPLICATION SUPPORT ARE PROVIDED BY DR. JOHNSON

WEB SITE:
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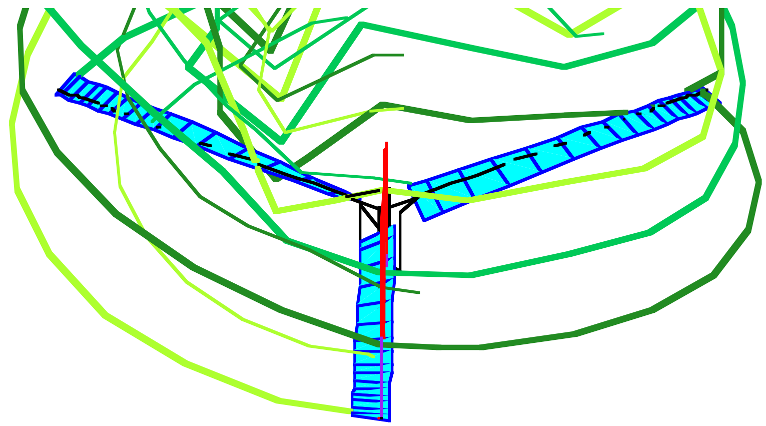


ROTORCRAFT ANALYSIS IS A COMPUTATIONALLY INTENSIVE TASK

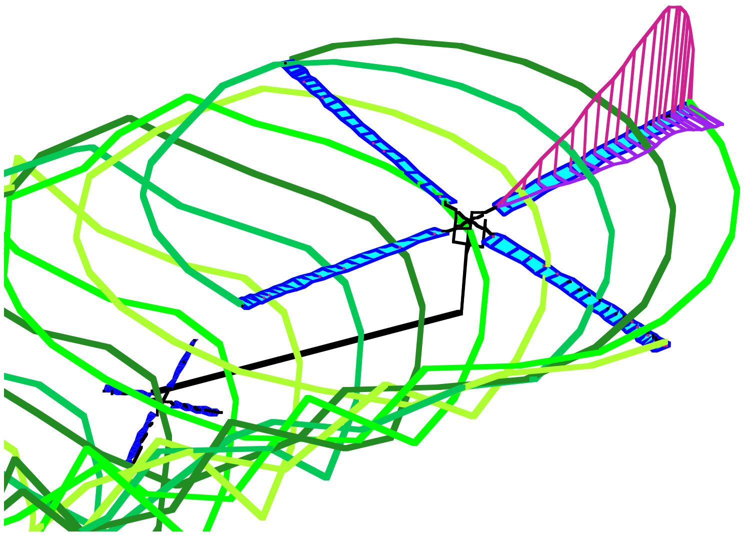
SO TYPICAL INSTALLATION IS ON A UNIX WORKSTATION

- SGI, HP, SUN, DEC
- ALSO DEC VMS, PC LINUX
- OTHER PLATFORMS

ROTORCRAFT ANALYSIS

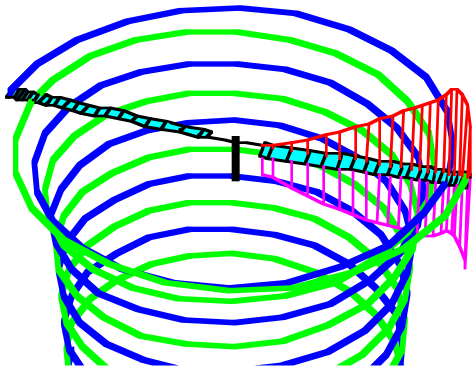
IT IS DIFFICULT TO ANALYZE ROTORCRAFT

- COMPLEX, MULTIDISCIPLINARY SYSTEM
  - STILL A LOT WE DO NOT KNOW ABOUT AERODYNAMICS, DYNAMICS, AND STRUCTURES OF ROTORCRAFT
- STILL NEED ENGINEERING JUDGEMENT, EXPERIENCE, AND MUCH TESTING OF THE ACTUAL SYSTEM



IT IS IMPOSSIBLE TO ANALYZE ROTORCRAFT EFFECTIVELY WITHOUT THE PROPER TOOLS

CAMRAD II IS A SOPHISTICATED AND MATURE AEROMECHANICAL ANALYSIS OF HELICOPTERS AND ROTORCRAFT



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