Constellation X-ray Mission
Spectroscopy X-ray Telescope:
Full-shell optics development and evaluation

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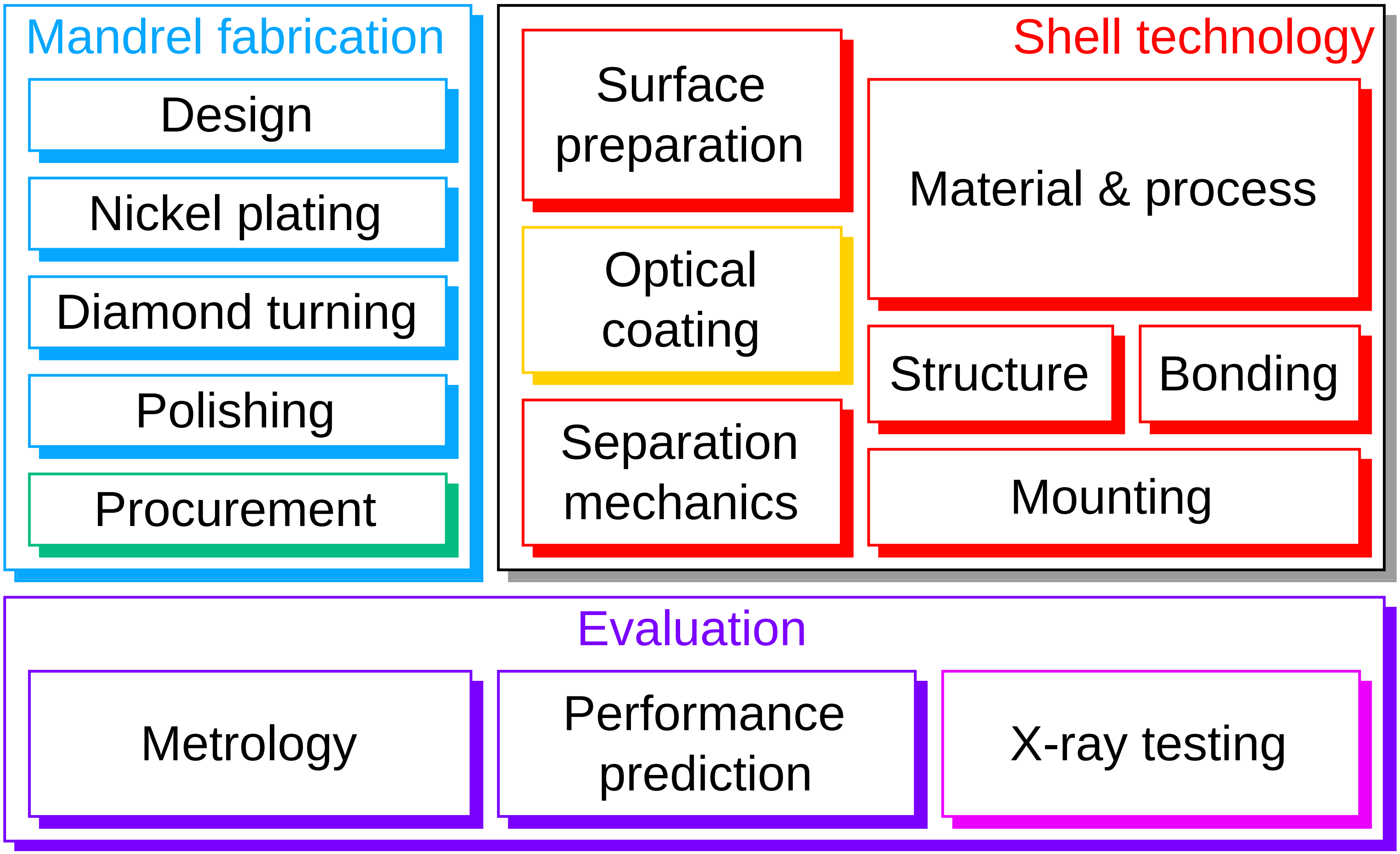
Development and evaluation tasks



Goals for 2000

- Mandrels
  - With Project, evaluate cost and schedule for production mandrels.
  - With Project, begin acquisition of meter-class precision mandrel.
  - Start modification of infrastructure to handle meter-class mandrels.
- Optics
  - Meet metrics for 0.5-m-diameter optics.
    - Replicate 1-kg optic to meet flight-weight requirement.
    - X-ray test optic to meet 10-arcsec-HPD allocation.
  - Develop integral stiffening structures.
  - Start modification of infrastructure to handle meter-class optics.
- Assembly
  - Conduct trade study of where to provide stiffness (optic or mount).
  - Develop and investigate concepts for alignment and assembly.

Replicated-optics challenges

- Mandrel fabrication
  - Requirements
    - < 5″ geometric half-power diameter (HPD_{geom})
    - < 5-Å surface finish for spatial frequencies > 1 mm^{-1}
  - Need mandrels up to *1.6-m* diameter (*1.0-m* length, tentatively).
    - Carl Zeiss (Germany) has demonstrated capability up to 0.7 m.
    - MSFC is refining fabrication/metrology to achieve capability.
- Shell technology
  - Requirements
    - Reduce mass to 1/6 that of demonstrated technologies (*XMM*).
    - Maintain figure and finish during separation from mandrel.
  - Developed two key shell technologies.
    - Developed high-microyield-strength (nonductile) nickel alloy.
    - Identified robust overcoat to control surface adhesion.

Mandrel status

- Small mandrels for process development
  - Diamond turned and polished dozens of 3-cm cone mandrels.
  - Have a few 6-cm (Wolter-1) mandrels for shell-technology research.
- Medium mandrels for replication
  - 25-cm (Wolter-1) 2-piece mandrel
    - Will use for non-integral-shell experiments with existing carriers.
    - Mandrel has poor figure; may need to repolish or replace.
  - 50-cm (Wolter-1) mandrels
    - Have one pathfinder mandrel for process qualification.
    - MSFC fabricated one precision mandrel (10-arcsec HPD).
    - Project purchased two precision mandrels (5-arcsec HPD) from Zeiss.
- Large (meter-class) mandrels
  - Project is investigating purchase of meter-class mandrels.

Infrastructure status for meter-class optics

- Coating
  - Large coating chamber is operational and in use.
- Plating
  - Medium plating bath is contracted and in use.
  - Large plating facility will be completed by 2000 Spring.
- Separation
  - Medium separation fixture is operational and in use.
  - Meter-class optics will require new separation system.
- Metrology
  - Vertical Long-Trace Profilometer is operational and in use.
    - Are working to improve accuracy and repeatability.
    - Meter-class mandrels will require some modification.
- Are conducting a more thorough inventory of meter-class readiness.

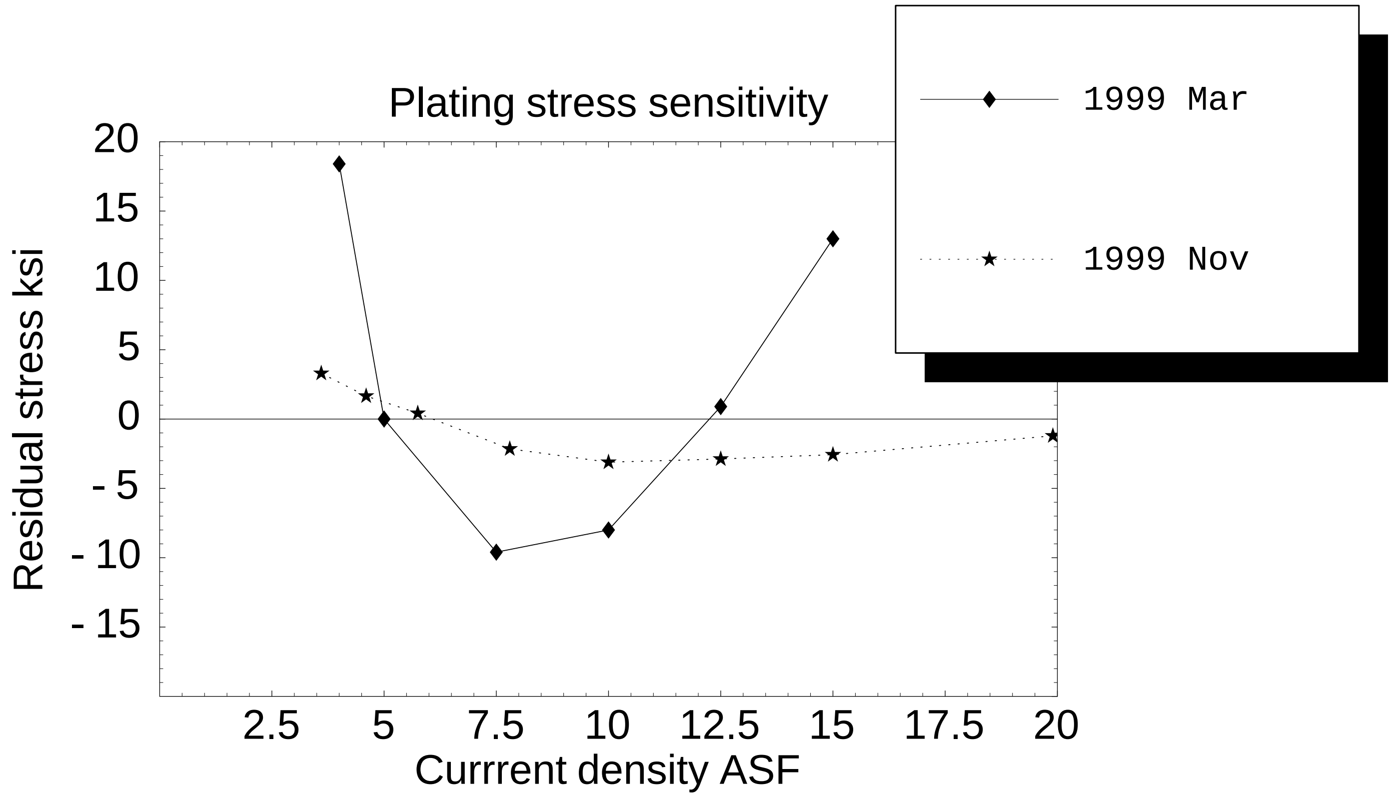
Shell processes under investigation

- Integral shells (led by MSFC)
    - Electroformed high-strength nickel alloys, at MSFC
        - Low deposition temperature and dimensionally stable
        - Low residual stress and low cost
        - No plastic deformation of new alloy, allowing thin walls
        - Lightweighting by electroforming ribbed, thin-walled structures
    - Plasma-sprayed ceramics, with Plasma Processes Inc.
        - Lightweight optics, even with uniformly thin shell
        - Low cost; also suitable for near-net-shape nonintegral shells
- Nonintegral shells (led by SAO)
    - CVD silicon carbide, with Morton Advanced Materials
        - Lightweight optics, even with uniformly thin shell
    - Fiber-reinforced plastics, with Composite Optics Inc.
        - Very lightweight optics, even with uniformly thin shell

Shell-technology status

- Have identified and successfully used passivation coating.
  - Encountered problems, primarily due to inadequate cleaning.
- Have developed various high-strength nickel-alloys.
  - A glass-like (nonductile) alloy gives highest microyield strength.
    - Have achieved low stress sensitivity, but slightly compressive.
  - A slightly ductile alloy may give adequate microyield strength.
    - Have achieved low stress sensitivity, at near-zero stress.
  - Have reduced variation in current density across mandrel.
- Are resuming research in plated structures.
  - Integral structures will stiffen thin-walled optics.
  - Alternative is to provide stiffness through mounting.
- Are investigating techniques for cutting to length.
  - Eliminates end effects (stress and pitting); allows focus adjustment.

Plating-stress sensitivity of glassy nickel



- Reduced variation of residual plating stress across shell.
  - Reduced sensitivity of plating stress to current density.
  - Reduced variation of plating current density across mandrel.

Electroforming on MSFC 0.5-m-diameter mandrels

- MSFC pathfinder mandrel (50M3).
  - Have used and continue to use for process qualification.
- MSFC precision mandrel (50M1) — HPD ≈ 10-arcsec.
  - Replicated (1999 May) a 4-kg shell. (Flight weight is about 1 kg.)
    - X-ray tested (1999 May).
    - Variations in plating stress caused degraded performance.
  - Replicated (1999 May) a 2-kg shell for display.
  - Replicated (1999 Nov-Dec) three 1-kg (flight-weight) shells.
    - Broke two in separate handling incidents after separation.
    - X-ray tested (1999 Dec) unbroken shell.
    - Poor mounting to stiffening ring (0.25-mm-amplitude variations in bond line) severely degraded performance.
    - Have debonded shell and remounted on stiffening ring, with mandrel as holding form.
    - Will conduct metrology (2000 Jan) and x-ray test (2000 Feb).

Plans for Zeiss 0.5-m-diameter mandrels

- Zeiss precision mandrels (50Z1 and 50Z2) — HPD < 5 arcsec.
  - Project ordered (1998 Oct) and received (1999 Aug) 2 mandrels.
    - At time of order, MSFC had not produced a precision mandrel.
  - Project will use one for segmented and nonintegral-shell optics.
  - Will use other (primarily) for integral full-shell optics.
    - Have built interface hardware for metrology; are building interface hardware for full-shell optics production.
    - Plan to replicate and x-ray test 1-kg (flight-weight) optic.
- Issues in first use of Zeiss mandrels
  - Minimize potential for damage to these high-quality mandrels.
    - Resolve degradation of passivation coating on 50M1.
    - Determine how to remove residual gold (for segment replication).
    - Verify processes on 50M3 (pathfinder) or 50M1 first.
  - Complete fabrication of interface hardware.

Issues for full-shell SXT optics

- Shells
  - In principle, electroformed nickel alloys should meet requirements.
    - Material is strong and plating-stress variations are low.
    - Have already electroformed 3 flight-weight shells.
    - Still need to demonstrate required optical performance.
  - Other materials may save weight or provide higher stiffness.
    - Residual stress will probably necessitate non-integral approach.
- Mandrels
  - Size and weight considerations make scale-up a technical concern.
    - Identify specific problems; seek solutions and alternatives.
  - Cost and schedule are a programmatic concern.
    - Identify requirements for long-lead-time infrastructure.
- Alignment and assembly
  - Evaluate trade between stiffness in shell or in mount.