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Condition Based Maintenance for Legacy Aircraft

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Making Machinery More Effective

Overview

- Integrated Health Monitoring (IHM) Program for Canadian Air Force Sea King fleet
- Systematic development, qualification and implementation of condition assessment methods to address specific maintenance/downtime drivers
- Judicious application of mature, reliable sensor technologies
- Integration of oil, vibration and performance analysis techniques
- Significant impact/benefits have been realized and quantified

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CF Sea King Helicopters

- 1963
- 28 Sea Kings
  - 12 Wing Shearwater, Nova Scotia
  - 443 Maritime Helicopter Squadron
- Deploy Worldwide
- Comprehensive Preventative Maintenance
  - O Level inspection & servicing
  - I Level detailed strip down and inspection
  - Contractor overhaul at Depot level
- Planned removal from service
  - 2012 to 2015
  - New Maritime Helicopter scheduled for 2008

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The Legacy Aircraft Problem

- Aircraft are older than pilots flying them
- Preventive, time based maintenance program requires significant manpower
- Obsolescence – new parts are difficult to find, require special production lines and long lead times
- Reliability issues no longer addressed by OEM component improvement programs
- Sea King status as of mid 1990's

  - excessive downtime
  - high maintenance man-hours per flying hour
  - unacceptable aircraft availability

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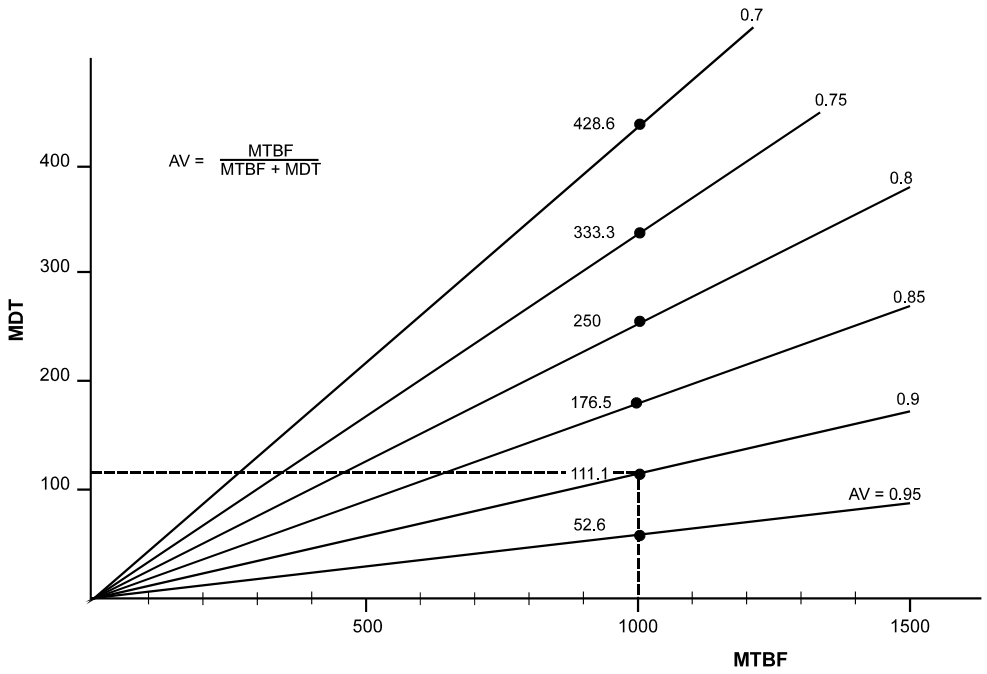
The Availability Plot



- MTBF = Design Issue
- MDT = Maintenance Issue
  - Reporting the Event
  - Mobilizing Crew
  - Condition Assessment
  - Physical Repair
  - Confirmation Test
- MDT can be improved by IHM, thereby improving availability

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General Approach to Problem Resolution

- Initiation of IHM Development Program (1997)
- Establishment of IHM Center of Expertise
- RCM analysis – to identify key failure modes and their effects
- Qualification and implementation of condition assessment methods
- Central, integrated database for IHM data management and analysis

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Integrated Health Monitoring (IHM) Program

- CAF contracted GasTOPS to develop and provide comprehensive IHM program
  - Company brought knowledge, expertise, continuity of personnel
- Control & coordination located at 12 AMS Shearwater
- Assets at
  - 12 Wing Shearwater, NS and 443 Maritime Helicopter Squadron, BC
  - Engine overhaul, Vancouver, BC
  - Gearbox overhaul – Mississauga, ON
  - Airframe contractor – Halifax, NS
- Set up Center of Expertise at IHM shop at 12 AMS
  - A DND / Contractor partnership
  - Also became training center

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IHM Shop Capabilities

- Fluids Analysis
  - Atomic Emission Spectrometry
  - Analytical Ferrography
  - Hydraulic Particle Counting
  - Filter Debris Analysis
  - Fuel Hydration
  - Seta Flash
- Vibration
  - Rotor Track and Balancing
  - High Speed Shaft Balancing
  - Gas Turbine & Gearbox Monitoring & Diagnostics
  - Precision Shaft Alignment
  - Advanced Diagnostics
- Thermography

All Personnel Fully Certified Condition Monitoring Specialists.

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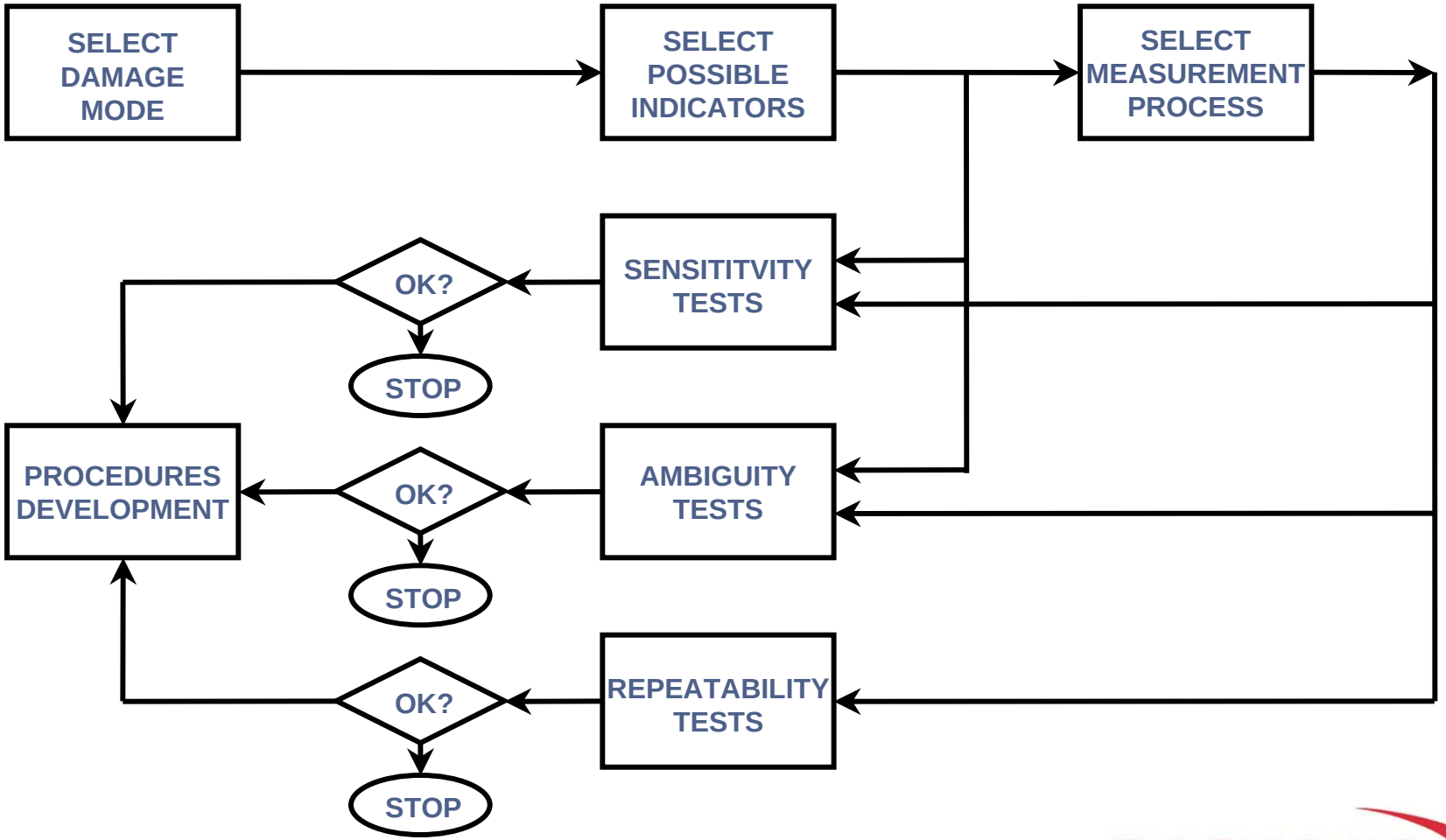
Qualification of Condition Assessment Procedures



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Engine Vibration - Problems

- Engine test cell – broadband vibration monitoring
  - Installed engine – discrete frequency monitoring
    - > Many engines passed at test cell but failed on-wing
- In addition, OEM test facility had fundamental differences in structural design and engine installation
  - but used same broadband criteria as test cell
    - > Passed OEM but failed test cell
- Discrete frequency vibration data from installed engines also identified misalignment and imbalance problems
  - Could be rectified at overhaul facility
    - > Thus extend the time on wing

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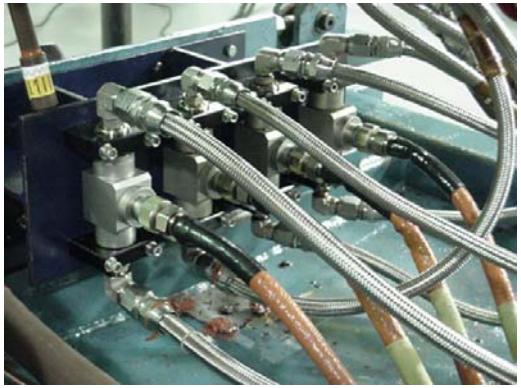
Engine Vibration - Solutions



- Eliminate differences between contractor ETF, 12 AMS ETF and on-wing programs
- All now use same vibration analyzer
  - Statistical VA limits developed
  - Oil debris monitors (ODM) installed in both test facilities
  - All data collection and analysis standardized
  - Results corroborated before engine declared serviceable.
- Imbalance and alignment problems investigated
  - New high speed in-situ balance procedure developed
- Vibration amplitudes reduced by 60 – 70%

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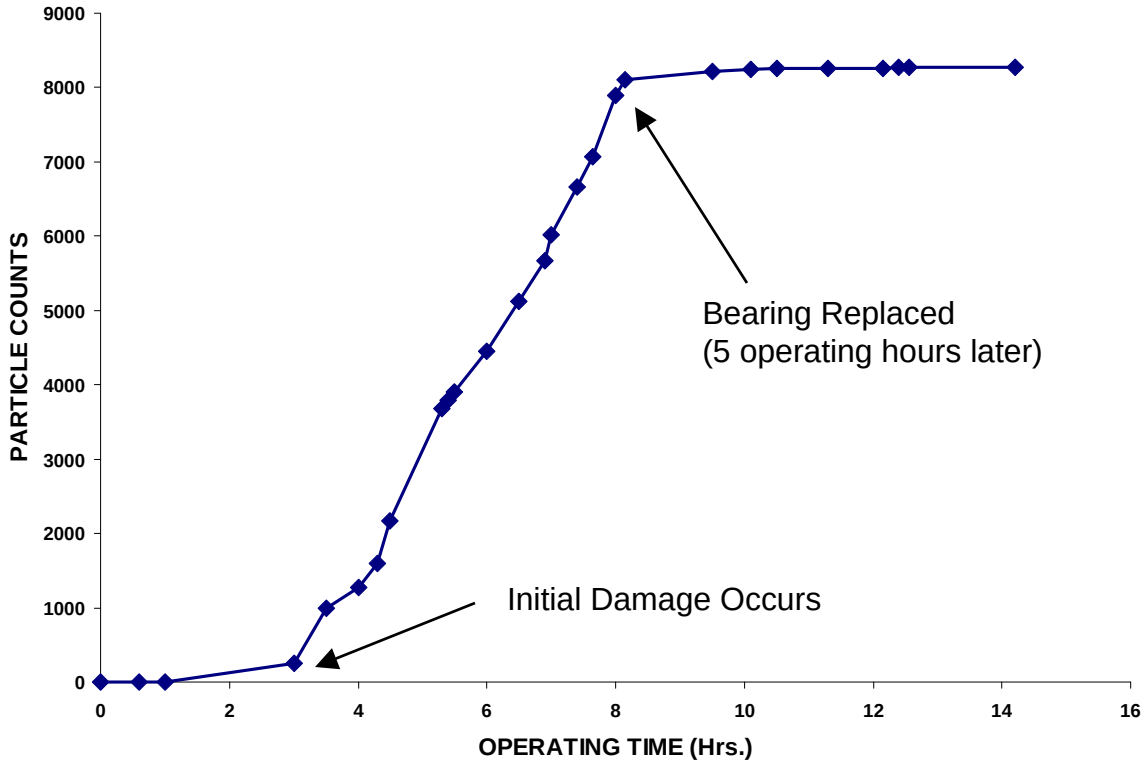
Bearing Damage - Field Data



- New engine run on test stand
- Damage due to mis-assembly
- Bearing highly overstressed
- *NO SECONDARY DAMAGE occurred*

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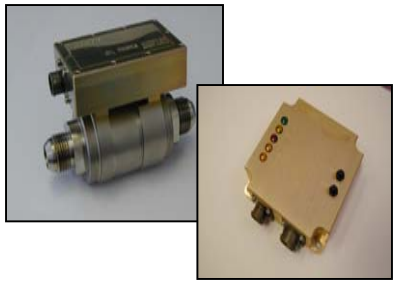
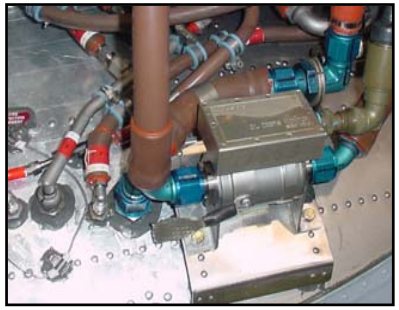
Engine Oil Debris Monitoring





- Laboratory spectrometric oil analysis program on-shore
  - In mid 90's engine failure occurred while deployed at sea
  - Oil samples "stored" until return to port
    - > Engine problem evident in stored samples
- Deployment of oil lab at sea recommended by Flight Safety
  - Shrinking staffing and expertise prohibited
- Solution: Install on-line, real time oil debris monitoring on engines

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Main Gearbox - Problems

- Gearboxes released from contractors test stand often failed prematurely for vibration and oil debris
- Review identified alignment and balance problems with test stand and VA criteria
  - R&O facility using OEM acceptance standards but aircraft had changed over 40 years
- Chronic problem of false chip lights

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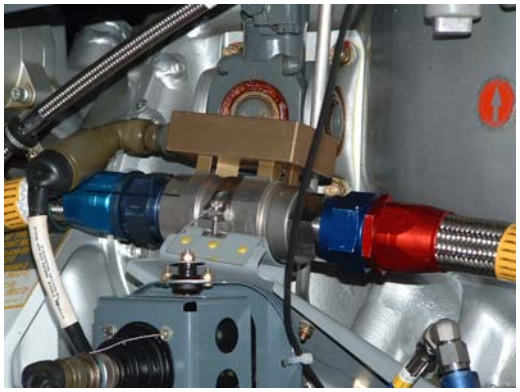
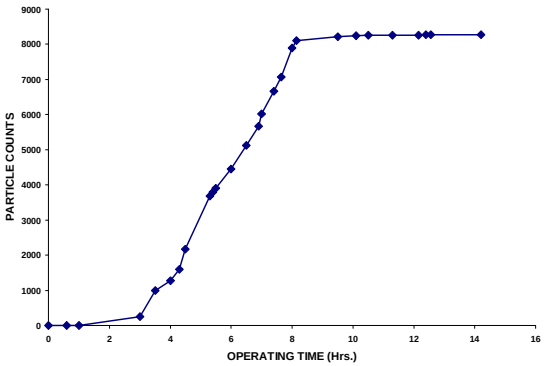
Main Gearbox - Solutions





- Test stand problems corrected
- New balance and alignment processes implemented
- New statistical vibration limits utilized
- ODM system installed on test stand
  - Successful in monitoring wear generation for early detection of assembly errors
  - Also ensured test stand runs were long enough to remove all break–in debris
- Eliminated false chip lights
- ODM currently being fitted to operational fleet for on-line monitoring

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Main Gearbox – Upgrade to 24000 Series Gearbox

- Upgrade started in 1999
- 10 micron filtration (previous model had been 46 microns)
  - Wear debris trapped in filter
- Developed automated Filter Debris Analysis program for O level maintenance support
- Automated system cleans and analyzes debris in 15 minutes (implemented 2000)
  - Upgrade in 2005 to incorporate metallurgical analysis by EDXRF
- Units deployed with Sea King around the world

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Continuous Improvement - MGB Case Study

- 3 chip detectors incidents in 20 flight hours
- Filters removed and processed with ship-board Filter Debris Analyzer - heavy debris - problem severe
- Oil sample and debris sent to IHM lab
  - Debris excessive - carbon steel
    - > Not traditionally associated with wear of critical components in MGB
- At R&O facility
  - Freewheel helical gear bearings severely worn
    - > One bearing completely disintegrated
    - > Cage - carbon steel with bonding coat of Ni and outer layer of Ag
    - > Ag not found in analysis - it was deposited by centrifugal force onto inside of spur gear housing
  - Ag had de-bonded from carbon steel base metal
    - > Ni was bond layer to adhere Ag to steel

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DAMAGED L/H FREEWHEEL BEARINGS

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MGB Case Study

- Why was bearing failure not identified properly by IHM program?
- Reason
  - Original Sikorsky 21000 series transmission free wheel unit utilized cages composed of brass or bonze alloy
  - Sikorsky 24000 series had different metallurgy - carbon steel
- GasTOPS tasked to develop methods to identify this problem early and monitor for safe operation
  - Until OEM could design and implement repair
    - ~2 to 3 years to upgrade fleet
- Solution: Presence of Ag or Ni - investigate
  - FDA units upgraded to include XRF on-site analysis
  - Vibration was not definitive due to random noise

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Tail Rotor Drive Shaft - Problem

- Shaft runs from main gearbox to tail rotor
  - Distance of >30 feet
  - Five sections and ten bearings
  - Life limit of shafts is 1125 operating hours
    - > However premature replacements not uncommon
- Investigation identified misalignment as significant reliability factor
  - Aligned with fish line and mechanical jigs
    - > Large variations due to temp, string sag, visual positioning
    - > Shaft deflections up to 0.150 vertical & 0.075 lateral were common

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Tail Rotor Drive Shaft – Solution

- Application of laser alignment technology
  - Space restrictions prohibited application of sweep type alignment
- Technique developed which mimics old string method with laser beams
  - Provides accurate digital data
  - Achieves <0.010 deflection of shaft in both vertical and lateral direction
- Significantly reduces, if not eliminates, bearing problems
- Extended shaft MTBF
- Reduced shaft installation times

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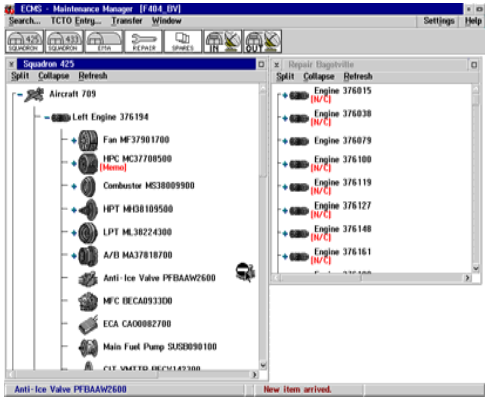
Data Management System



- Implemented new integrated IHM data management system
  - Usage tracking
  - Condition monitoring (performance, oil and vibration analysis)
  - Status monitoring
  - Reliability monitoring
  - Asset Management
- Used by all levels of maintenance for operational scheduling, maintenance planning and resource allocation
- Data fusion is key element of continuous improvement process based on IHM

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IHM Impact / Benefits

	Before IHM	After IHM
1. Aircraft Availability	34%	85%
2. Main Gearbox MTBR	850 hours	1350 hours
3. Engine MTBR	350 hours	450 hours
4. Major Periodic Inspections	550 hours	650 hours
5. Oil Samples	1600/year	200/year
6. Tail Drive Shaft Installation	10 days	2 days
7. IGB Installation	10 days	3 hours
8. False Chips Lights	Chronic Problem	Eliminated

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Summary

- Benefits of IHM for legacy aircraft are substantial
- Important take aways from Sea King program success
  - Focus on key maintenance/downtime drivers
  - Identify root failure causes by RCM analysis
  - Judiciously apply mature sensor technologies capable of identifying failure modes and quantifying their severity
  - Qualify condition assessment procedures before fielding them
  - Establish integrated database system to support qualification and continuous improvement processes

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Questions?

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