Landing Gear 101

John Salamankas

Landing Gear Recycling

- **Discussion: Request that Gulfstream provide guidance on the use of recycling the gear to achieve a normal gear configuration**
- **Action: Will review history of the practice and provide Gulfstream opinion.**
- **Status:**

Landing Gear 101

- **Purpose – Provide recycling guidance as requested**
  - **Facts**
  - **Logic**
  - **Opinions**
- **Recent events justify the request**
  - **Landing gear problems increasing in frequency**
  - **#2 Priority action item for RQAAT**
- **Goal**
  - **Offer a sound opinion**
  - **Same success as Brakes 101**

Outline

- History
- Gear System Basics
- Failure Modes
- Fleet Examples
- Considerations
- Opinions

History

- 40+ years on the jet fleet
  - Gear nearly same from G-II through G-550
- 2 Nose gear up landings, almost a 3rd
  - GIV packed with frozen slush
  - GV mechanical failure of critical part
  - G-II nose strut wiped with Skydrol rag
- Main gear has always come down
  - Aggressive maneuvering
  - Bounces and Scuffs
  - Improvised emergency procedures

History

- **Emergency system has always “worked” (Nitrogen released and routed to actuators)**
- **Sometimes unable to overpower a mechanical problem**
  - **Neither was 3000 psi hydraulic pressure**
- **One case where routed to a ruptured actuator**

Recent Trends

- G-1159 through G-VSP gear problems
  - Corrosion
  - Wear
  - Maintenance
    - Rigging and adjustments
- G-IVX , G-V, & G-VSP issues involve the above, plus
  - Electrical control (solenoid)
  - Hydraulic pressure bumps

Landing Gear Basics

- **Normal system**
  - **Control is mechanical or electrical**
  - **Power is Hydraulic**
  - **Indication is electric**
- **Emergency system**
  - **Control is mechanical**
  - **Power is pneumatic**
  - **Indication from normal system**

Gear Basic Function

- **Landing gear handle**
  - **2 position, UP/DOWN**
  - **Controls a Selector Valve**
    - **Routes hydraulic power to each landing gear**
- **3 gear operate independently of each other**
  - **Operating sequence is controlled by mechanical linkage**
- **“Gear Down” indication via independent electrical circuits**

Gear Basic Function

- **Differences between models are minor**
  - **Landing Gear Selector Valves**
    - **G-1159 and G-IV are mechanical with sliding spools**
    - **G-IVX, G-V,G-VSP are solenoid-controlled**
  - **Dump Valve**
    - **G-1159 and G-IV have separate dump valve**
      - **mechanical reset**
    - **G-IVX, G-V,G-VSP use combined selector/dump valve**
      - **reset is electric**
  - **Design operating pressure**
    - **1500 psi for G-1159**
    - **3000 all others**

Gear Basic Function

- **Emergency Extension**
  - **Mechanical control releases Nitrogen**
    - **Nitrogen pressure shifts dump valve**
      - **Return path to reservoir for up-side hydraulics**
    - **Dedicated routing for pressure to each gear**
    - **Shuttle valves on actuators for door, uplock, and gear**
      - **Shifted by nitrogen**
      - **Allow nitrogen to power the actuators open/down**
      - **Shuttle valves are common to normal & emergency systems**
    - **No sequencing or timing**
      - **Gear will push door out of the way**

Failure Modes

CONTROL

- **Handle or selector valve**
  - **Mechanical**
    - **Restricted movement**
    - **No movement**
  - **Electrical**
    - **Safety solenoid**
    - **Selector/Dump valve solenoid**
    - **Wiring & connections**

Failure Modes

HYDRAULIC POWER

- **Pump failure**
- **Fluid loss**

INDICATION

- **Only 1 switch per gear for “gear down”**
- **2 bulbs per capsule**
- **Ess DC power**
  - **Loss is possible but not likely**

Failure Modes

MECHANICAL SEQUENCING

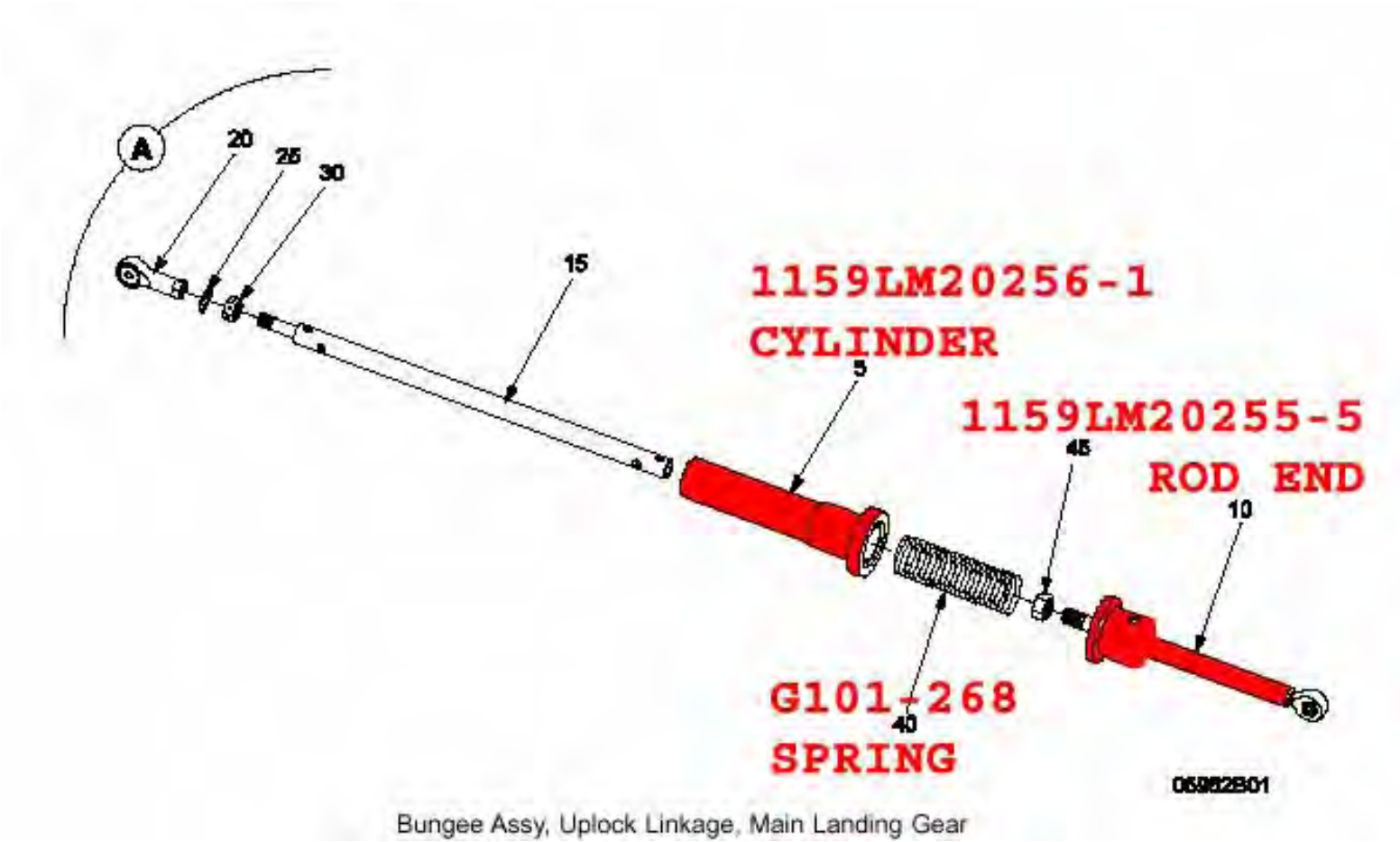
GEAR DOWN	GEAR UP
Doors Open	Doors Open
Uplocks release	Downlocks release
Gear extends	Gear retracts
Doors close	Doors close

Failure Modes

MECHANICAL SEQUENCING

- Sequencing linkage
  - Lightly loaded mechanical connection to valves
  - Positions valves to control flow to actuators
    - Doors
    - Uplocks
    - Landing Gear
  - Bungees
    - Spring-loaded units in the linkage
    - Extend to reposition valves
    - Maintain tension on the mechanical links

Failure Modes - Bungee



Bungee Assy, Uplock Linkage, Main Landing Gear

Failure Modes - Bungee

Magnification: 10X

Figure 20: Photomacrograph of the corroded surfaces of the spring

Failure Modes

MECHANICAL SEQUENCING FAILURES

- Linkage
  - Broken
    - Doesn’t move
  - Binding
    - Moves partially
    - Moves sometimes
    - Doesn’t move at all
  - Rigging out of adjustment
  - Result
    - Components don’t operate
    - Operate but interfere with each other

Failure Modes - Sequencing

Failure Modes – Sequencing/Hydraulics

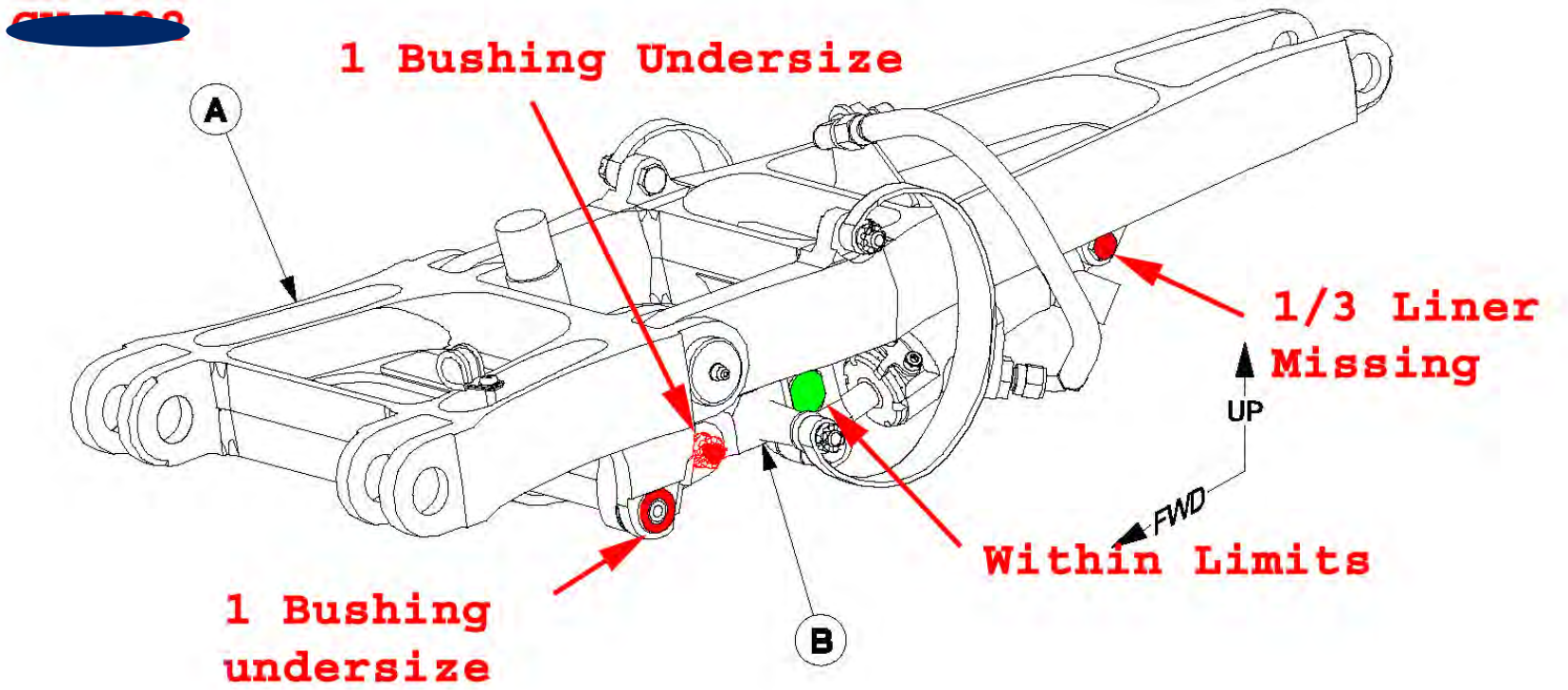
- **“Minor” difference in electrical vs. mechanical control proved to be significant**
- **Solenoid operation causes rapid spool shift**
  - **Pressure transients in gear lines**
    - **Positive (spikes)**
    - **Negative (suction force)**
    - **Transients greatest at end of lines (NLG)**
      - **G-V & G-VSP lines longer than G-IVX**
  - **NLG uplock actuator may shift toward open**
  - **Sequencing linkage moves door control valve to blocked ports region**
  - **NLG “slow to operate” or stays up**

Failure Modes

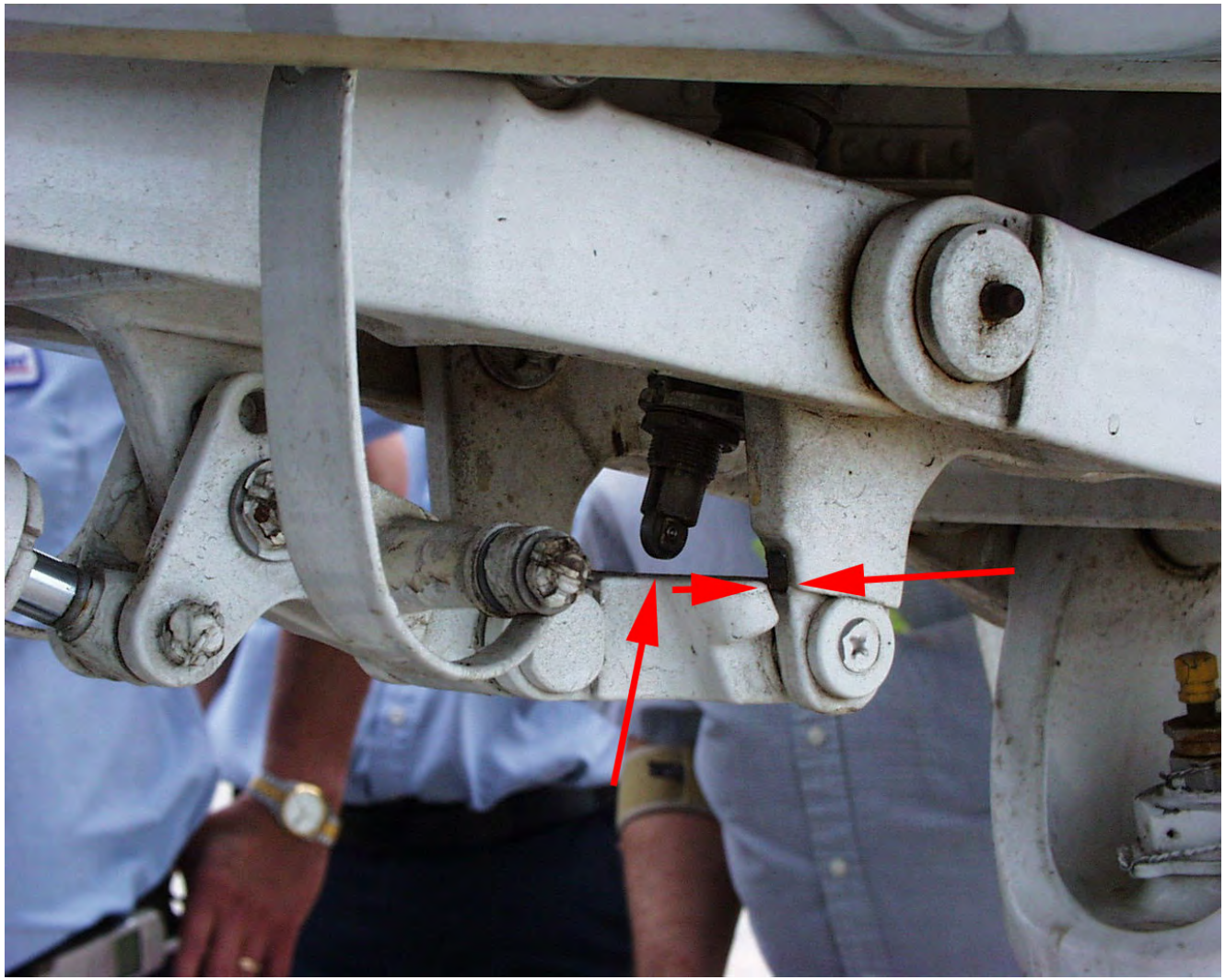
NORMAL WEAR

- **Bushings, Bearings, and Pins**
- **Parts move out of alignment and bind**
  - **Gear slow to extend**
  - **Gear may not lock down**
- **Most prevalent with NLG**
- **Same NLG symptoms as “pressure bumps”**

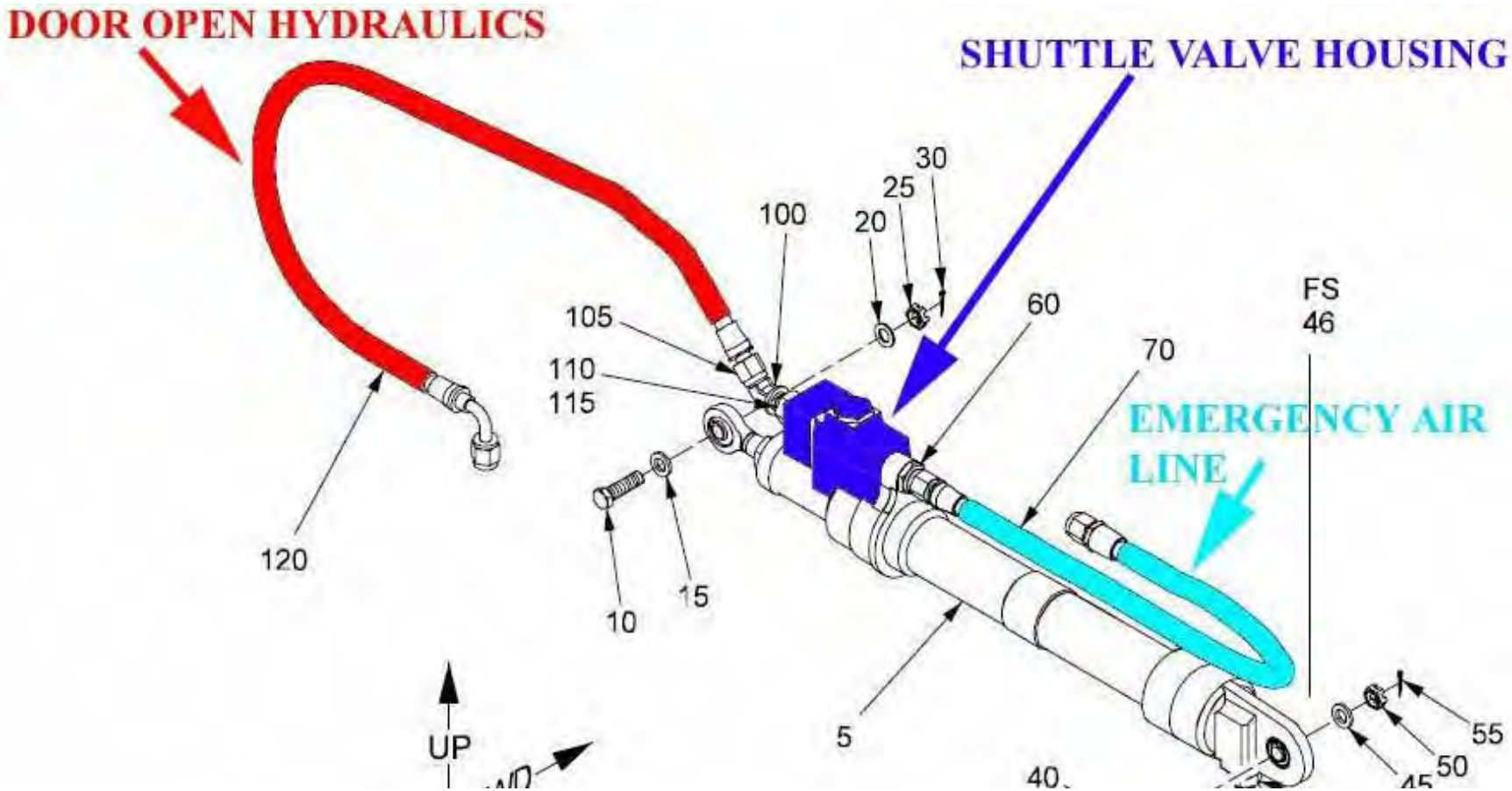
Failure Modes



Failure Modes - Wear



Failure Modes - Mechanical



Things to Consider

- **Cause of the problem**
  - **Hydraulic**
  - **Electrical**
  - **Mechanical**
- **Recent aircraft maintenance**
- **Recent gear behavior**
- **Inflight problems that can’t be duplicated on jacks are usually electrical**
- **Slow to operate may be binding, rigging, pressure jumps**

Things to Consider

- **No response to selection**
  - **Electrical – bad solenoid, wiring, or no power**
  - **Mechanical – dump valve shift or leakage**
- **Get any response to gear selection**
  - **Problem is not electrical (G-IVX, G-V, G-VSP)**

Recycling

- We recycle in the hope things will get better
  - Sometimes they do
- There is an equal chance they will get worse
  - Lately they have
- There is reluctance to use the emergency system because reset requires maintenance action
  - 40 man-hours
  - 1 day
- Aircraft with electrical control of gear selection may get a different hydraulic response by recycling
  - Better or worse

Recycling

- **Recycle something that's binding**
  - **May be freed**
  - **May stick in a worse position**
- **Aircraft with mechanical control of landing gear selector valve (G-1159 series & G-IV)**
  - **It makes no sense to recycle**
- **If unsure where some gear component is**
  - **It makes no sense to recycle**
- **If you know something is out of sequence**
  - **It makes no sense to recycle**

Recycling

- **Gear door OPEN with gear handle UP**
  - **Something is out of sequence, but**
    - **The open door is out of the way**
  - **Put handle back down to recycle**
    - **Door may interfere with gear**
  - **If gear goes down but doesn't lock**
    - **Bungee likely jammed in extended position**
  - **Retract gear so door is known to be clear**
  - **Blow the gear**
  - **Put handle down for normal indication**

Opinion on Recycling Gear

- Sources and their experience
- G-1159 series and G-IV (mechanical gear selection)
  - Do not recycle
- G-IVX, G-V, and G-VSP
  - Recycle once if no response to gear down selection
  - Recycle once if nose gear doesn't go down but both main gear do
- For all aircraft
  - If any gear does not retract after takeoff select gear down and return to the field for landing and troubleshooting on the ground.

More History

- There have been many cases where recycling has helped.
- There have also been many cases where it made things worse. Recently this is the trend.
  - Recycle to get something up, then not get gear down
  - Recycle to get something down, get less
- For 40 years there have been no cases where an emergency extension made things worse.

Questions